REPORT OF AN INVESTIGATION OF THE SPEARFISHES OF FORMOSAN WATERS

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By

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Introduction

This study of the spearfishes has been made as a part of an investigation of the important fishes of Taiwan. The study was begun in 1934 and thereafter specimens from catches landed at the Keelung, Suō, Shinkō, and Takao fish markets were studied, the anatomical work being done mainly on material obtained at Suō and on the catch of the research vessel Shonan Maru belonging to this laboratory.

The spearfishes (local name旗魚) are the most important element in the Formosan fish catch, the production in recent years being as shown in the table below (based on Taiwan fishery statistics). The value of these fishes is second only to that of the cultivated milkfish and occupies the first place among the catches of all fisheries.

Table 1.--Spearfish catch in six recent years

Year	Quantity	Value
	kin[1/]	yen
1935	7,066,111	1,361,706
1934	7,437,667	1,391,879
1933	5,362,462	1,024,685
1932	5,421,945	914,243
1931	6,545,973	1,025,223
1930	5,485,886	1,210,337

[1/] 1 kin = 1.32 lb.

During the course of an earlier study on the sharks of Formosa the author had opportunities to observe the handling of spearfishes in the fish markets frequently, because the fishing seasons for sharks and spearfishes coincide.

The spearfishes are classified into a number of kinds by the commercial operators and these varieties are handled separately, there being marked differences in their value. At first it was extremely difficult to distinguish these varieties, but in the course of many repeated observations the classification method of the commercial operators gradually became clear and the author became able to distinguish the peculiarities of each variety and arrived at the opinion that the classification made by the commercial people should be studied from the point of view of systematics.

During the course of this study I have been constantly guided by Professor Hirasaka of the Taihoku Imperial University, and for the illustrations I am indebted to Mr. Sakuma of the University. I also wish to express my thanks to all the persons in the fishing industry throughout the island who have shown great understanding and who have facilitated this study in many ways, and particularly to the Suō Suisan Kaisha.

I. Species

A. General

Among the systematic studies and publications concerning the spearfishes of Japan, D. S. Jordan and J. O. Snyder[1] have recorded two species. These are Tetrapturus mitsukurii, the makajiki, and T. mazara. Dr. Tanaka[2] had earlier recorded the following five species from Japan:

Family Istiophoridae, genus Istiophorus

1. Istiophorus orientalis

Genus Tetrapturus

2. Tetrapturus mitsukurii
3. Tetrapturus mazara
4. Tetrapturus angustirostris

Family Xiphiidae, genus Xiphias

5. Xiphias gladius

In recent years the same author has reported the following two species as representatives of the genus Tetrapturus. These are T. mitsukurii[3] and T. angustirostris[4], and he gives the following explanation with regard to them. "Species close to this one (the striped marlin) are called black marlin and white marlin at Tokyo, but it is not clear whether these are separate species or varieties within a single species." Accordingly the new species T. mazara recorded by Jordan and Snyder is in recent writings of Dr. Tanaka treated as the same species or a variety of the same species as T. mitsukurii. And although he does not clearly call for the suppression of T. mazara, in actuality it amounts to its complete suppression.

The writer knows nothing of the fish called black marlin and white marlin at Tokyo, but the fish called black marlin (or black-skinned marlin) and white marlin (or white-skinned marlin) at Formosa are of course different from the striped marlin and these two species certainly are not identical. If it is supposed that the commercial operators at Tokyo apply these several names to the several species in the same way that they are used in Formosa, the quotation above cited from Dr. Tanaka should not be "black marlin or white marlin" but "black marlin and white marlin" and instead of speaking of "both of these species" he should speak of "these three species."

D. S. Jordan and B. W. Evermann[5] have divided the spearfishes of the whole world into two families and four genera and record 32 species, 20 of them for the Indo-Pacific region. F. Day[6] [7] has reported three species, Histiophorus gladius, H. immaculatus, and H. brevirostris from the Indian Ocean. From South Africa K. H. Barnard[8] has reported H. gladius and Makaira herscheli.

1/ Jordan and Snyder. 1901, Jour. Coll. Sci. Imp. Univ., Tokyo.

2/ Tanaka, Shigeo. Japanese Ichthyology, Volume 1, 1921.

3/ Tanaka, Shigeo. Illustrated atlas of useful, harmful, and admirable aquatic animals and plants, 1933.

4/ Tanaka, Shigeo. Fishes of Japan, Vol. 1, 2nd edition, p. 324, 1935.

5/ Jordan and Evermann: Occ. Papers Calif. Acad. Sci. XII, 1926.

6/ Day F. Fishes Ind., Vol. 1, pp. 198-199, 1878.

7/ Day, F. Fauna Brit. Ind., Fish, Vol. 2, 1889.

8/ Barnard, K. H. Ann. South Africa Mus., Vol. 21, Part 2, 1925-1927.

Of these species M. herscheli from South Africa is, according to Lütken[9/], the same species as T. brevirostris of the Indian Ocean, and according to K. H. Barnard H. gladius is a synonym of H. indicus.

The lack of agreement and state of complete confusion among the opinions of the various authors may be thought to be due perhaps to the fact that these fish are very large, handling and study of them is inconvenient, and the preservation of type specimens is difficult. It is thought that another important cause is that in many cases the specimens used in the studies were incomplete. In many cases the commercial fishermen customarily cut off and throw away the long snout, which is without any practical value. For example, it appears that the two species recorded by Jordan and Snyder from Japan were based on studies made of incomplete specimens at Misaki in Kanagawa Prefecture.

The spearfishes taken in Formosa are distinguished by the commercial operators as follows:

1. red spearfish - akakajiki or aka /striped marlin/*
2. black marlin - kurokajiki or kurokawa kajiki
3. white marlin - shirokajiki or shirokawa kajiki
4. sailfish - baren or bashōkajiki
5. a species with no definite name (furaikajiki) /the shortnosed spearfish/
6. broadbill - tsun or mekajiki

Among these, species 1 to 5 belong to the family Istiophoridae, 6 belongs to the family Xiphiidae. The sailfish, shortnosed spearfish, and broadbill, because of their peculiar form, are easily distinguished from the other three, and are also easily differentiated from one another. The problem is in whether species 1 to 3 are, as Dr. Tanaka has said, actually one species or two species or whether the three should all be treated as separate species.

According to Jordan and Evermann, the genus Istiophorus includes four species from the Indo-Pacific region, with perhaps a still different species from Formosa, but the sailfish of Formosa is the same species as that of Japan proper and no other species is known up to the present.

The red marlin /striped marlin/, black marlin, and white marlin also have clear morphological characteristics and can easily be distinguished by a slightly practiced eye, the differentiation being extremely easy even in the case of specimens which have had their heads and tails cut off.

B. Morphological Comparison

As has been stated, the spearfishes have conspicuous external characters which make it easy for an experienced eye to distinguish between them at a glance, but it was thought that morphologically, rather than such external elements as coloring and markings, internal elements such as differences in skeleton and musculature are more important and fundamental. Accordingly it is believed that external morphological differences should be corroborated by comparisons of skeleton and musculature, and at the same time it is thought that a considerable contribution to taxonomy may result from these comparisons.

With the object of eliminating, insofar as possible, observational errors due to individual peculiarities, the author wished to inspect and dissect as many specimens as possible, however, it was difficult to tell how many specimens would be sufficient, and, except in particular cases, the individual peculiarities are not striking enough to require consideration; consequently dissections have been performed upon only the following numbers of specimens.

9/ Jordan and Snyder. Jour. Coll. Sci. Imp. Univ., Tokyo, 1901.

* Translator's note: Akakajiki, literally "red spearfish", is evidently the name applied in the Formosan fishery to the striped marlin, which is called in Japan makajiki, literally "true spearfish."

Species	Number	Female	Male	Sex undetermined
Striped marlin	16	7	9	-
Black marlin	5	3	2	-
White marlin	5	2	3	-
Sailfish	3	-	-	3
Shortnosed spearfish	11	6	5	-
Broadbill	3	-	-	3

As a result of the observation of the above specimens it appears that the greatest amount of individual variation is found in the shape of the cranium, so that it would be difficult to recognize any basic form for it. In the case of the vertebrae and the so-called membrane bones, although there was more or less individual variation, the basic forms were comparatively clear and they were convenient for carrying out comparisons among the species.

1. External form

(a) General appearance

The most conspicuous characteristic of the spearfishes is a sword or spearshaped upper jaw formed by the prolongation of the premaxillary, maxillary, and nasal bones. The principal bones making up the elongated upper jaw are the premaxillary and the nasals, the maxillary itself attaining only one-half the length of the upper jaw as a whole.

In the broadbill swordfish the snout is conspicuously flattened and broad, having the shape of a double-edged sword, but in the Istiophoridae it has the form of an elongated cone with a roughly circular cross section. The note of Jordan and Evermann[10/] in regard to this point, "upper jaw prolonged into a spear or sword which is shorter and narrower and more flattened on the edge than in the true swordfish or broadbill" can hardly be thought to be based on complete observations.

Generally the bodies of the spearfishes other than the broadbill are markedly longer and at the same time more laterally compressed than those of the scombroid fishes, which are considered to be most closely related to them. In the Istiophoridae generally, in differing degrees the outline of the dorsal surface projects conspicuously anterior to the origin of the first dorsal fin, with a gradual slope posteriorly from this part to the caudal peduncle. The ventral profile is somewhat swelled out in the vicinity of the base of the ventrals but to a far less conspicuous degree than in the case of the dorsal projection.

The greatest body depth is measured between the origin of the ventrals and between the third spine and the second soft ray of the first dorsal, the line passing just through the posterior end of the base of the pectoral fins. If the head is cut off on this line, the rest of the body forms an almost regular trapezoid, although the bases of the second anal and the second dorsal project somewhat. The trunk is more or less compressed laterally and the caudal portion is roughly round, the cross section through the caudal peduncle being circular. The degree of lateral compression is most striking in the shortnosed spearfish, followed by the sailfish, and is least conspicuous in the black marlin. In the broadbill, except for the snout, the body of the fish is a well proportioned spindle shape, the trunk is short, and the projection on the dorsal profile is far less conspicuous than in the case of the istiophorids. The istiophorids have two pairs of keels on the caudal peduncle, while the broadbill has a single pair of very large ones.

Among the istiophorid fishes the body depth is greatest in the white marlin and least in the shortnosed spearfish, there being quite striking differences among the species in the

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10/ Jordan and Evermann. Occ. Papers, Calif. Acad. Sci., XII, 1926.

proportion of body length* to body depth, these proportions being 4.460 for the white marlin, 4.561 for the black marlin, 5.231 for the striped marlin, 6.371 for the sailfish, and 6.881 for the shortnosed spearfish. However, the body depth used here was measured along the curved surface of the side of the body, so in actuality the ratio between body length and body depth should be larger. Experiments on several fish of each species showed that, although there are differences among the species, the ichthyological body depth is 83 to 86 percent of the body depth measured over the curved surface of the side. Because the fishes are so large, it was impossible to measure the body depth as ordinarily used by ichthyologists, and as there is considerable danger of error in converting the measured values to the ichthyological body depth in accordance with the above mentioned experimental measurements, it was decided to use the body depth as measured over the curved surface of the side.

The black marlin differs from the other fishes of the genus Tetrapturus in that the body tends conspicuously toward a cylindrical form, and the body depth at the origin of the first anal fin is greater than in the other species, being only slightly less than the greatest body depth. The body depth at the origin of the first anal fin is greatest in the black marlin and smallest in the shortnosed spearfish, the ratios between the body length and body depth at this part in the two species being 5.682 for the black marlin and 7.900 for the shortnosed spearfish (plate 1).

The size of the fish differs among the species, the white marlin attaining the most gigantic proportions. The largest fish of this species encountered by the author during his investigation measured 2,713 millimeters from the posterior edge of the eye to the caudal peduncle. From the author's data and from the reports of experienced commercial operators it appears that the order of size of these fishes of the family Istiophoridae is white marlin, black marlin, striped marlin, sailfish, and shortnosed spearfish. It is said that there are very large broadbill swordfish, but at Taiwan no specimen greater than 1,500 millimeters in body length without the sword has been seen (plate 2).

(b) Coloration and markings

In the broadbill the dorsal surface is a deep blackish brown, with a bluish tint in the fresh specimen, and the belly is yellowish white. The blackish brown color of the back becomes gradually lighter along the sides and the boundary between it and the belly color is indistinct. All of the fins are dark blackish brown and there are no markings or spots anywhere on the body nor do the belly or the opercles have any shining silvery coloration.

In the fishes of the family Istiophoridae in general the dorsal surfaces are dark purple with an indigo tint and the bellies are shining silver. The boundary line between these two colorations is comparatively clear and forms a finely serrated straight line paralleling the dorsal profile rather than running along the exact center of the sides of the body. When the fish are fresh and the slime has not yet dried, all of the fins except the first dorsal and the first anal are a deep blue-black color. In specimens which have been exposed to the air for a long time the color of the fins changes to a blackish brown. When dried, the first dorsal and the anal fins are also a deep blue-black, but when they are fresh these two fins are a bright cobalt blue. In specimens which have already been exposed to the air for a long period of time and in which the projecting portions of the first dorsal and anal fins have changed to a deep blue-black color, if the covered portions of the fins are taken out and examined it is found that the covered moist portions are bright cobalt blue and thus it may appear that those portions have a particular marking, however, this color /difference/ is not a marking which appeared on these fins in life.

The black marlin is so called because the silvery white portion of the belly is covered with a brown slime having a purplish tint and the coloration of the whole body is conspicuously tinged with brown. In white marlin which are fresh and from which the slime has not yet been removed

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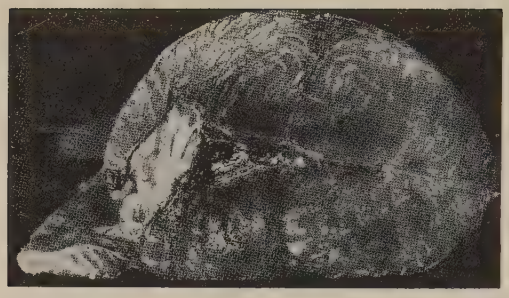
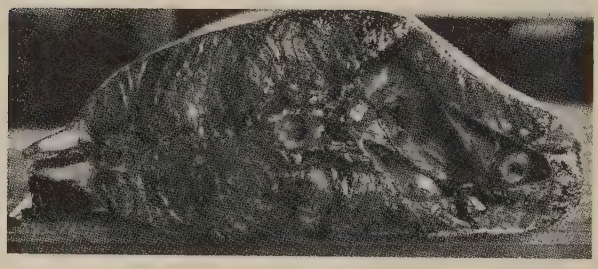
*Translator's note: According to a personal communication from the author, the "body length", where not otherwise defined, is the total length from the "tip of the snout to the caudal peduncle."



A - black marlin

B - striped marlin

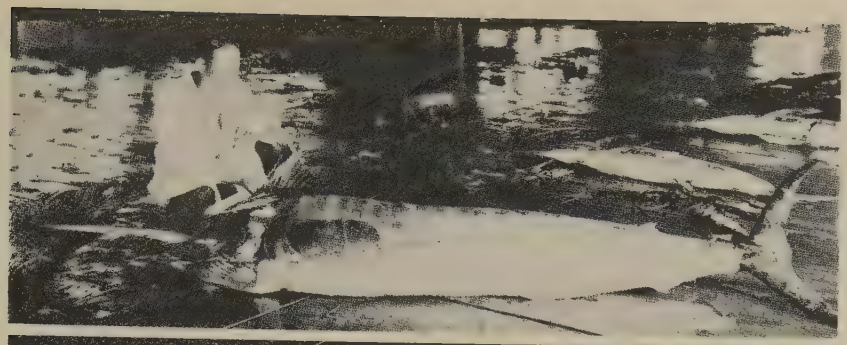


C - sailfish

D - shortnosed spearfish

E - white marlin

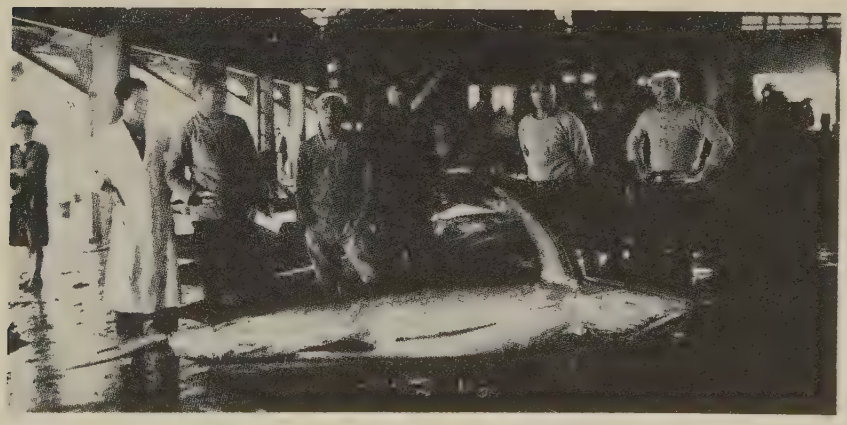
Plate 1.--Cross sections of spearfish (cut at the tip of the pectoral fins).



A

B

C



D

Plate 2.--Three species of the genus Makaira. A - white marlin; B - black marlin; C - striped marlin; D - a gigantic white marlin.

Table 2. --Proportions of various parts of the fish

Species	Body length-head length	Body length-body depth$_1$	Body length-body depth$_2$	Body length-snout length	Head length-snout length	Snout length-head length$_1$	Head length$_1$-eye diameter	Upper jaw-lower jaw	Head length-intereye space	Intereye space-eye diameter	E -- D eye diameter	Body depth$_1$-caud.ped. depth	Body depth$_1$-pect. fin	Body depth$_1$-I. D.
Black marlin (24)	2.758	4.561	5.682	2.965	1.525	2.546	4.132	2.211	5.696	2.514	4.215	5.905	1.199	1.535
White marlin (36)	2.771	4.460	5.845	3.136	1.523	2.291	4.830	1.946	5.750	3.034	4.333	6.124	1.142	1.613
Striped marlin (34)	2.613	5.231	6.911	2.804	1.496	2.449	4.138	1.846	6.123	2.373	4.091	4.910	0.947	1.053
Sailfish (8)	3.188	6.301	7.819	2.828	1.403	3.058	3.725	2.197	7.661	2.353	3.793	4.653	0.899	0.797
Shortnosed spearfish (12)	3.868	6.881	7.900	6.278	--	1.386	3.333	1.281	--	--	--	3.806	6.859	--
Broadbill (6)	1.846	5.187	5.923	1.399	1.328	3.771	3.672	3.787	8.688	1.967	3.370	7.382	1.319	1.071

Body depth$_2^1$ is the greatest body depth.
Body depth$_1$ is the body depth at the origin of the 1st anal fin.
Head length$_1$ is the length of the head excluding the portion anterior to the posterior edge of the eye.
Numbers in parentheses under species names are the numbers of fish measured.
E -- D Distance from eye to 1st dorsal fin.
I. D. Height of 1st dorsal fin.

the dorsal surfaces are of a pale blue color with a milky tint and the impression given by the coloration as a whole is that of pale blue or gray blue, the name being due to the fact that the coloration is conspicuously paler than in any of the other species. In the sailfish the deep blue-black portion of the back is broad in extent, while in the shortnosed spearfish the belly is a clear silvery white and the dorsal surface is the color of steel.

In the white marlin and the shortnosed spearfish there are no spots or markings of any kind on any part of the body, but in the black marlin, sailfish, and striped marlin there are fifteen or more transverse bands of bright cobalt blue or a cobalt with a whitish tinge. These transverse bands do not extend clear across the dorsal and ventral surfaces but are present only in the middle of the sides. If the fish is left exposed to the air for a long time these markings gradually fade or completely disappear, but if water is poured on the fish and the sides are lightly rubbed the markings will again appear clearly. The markings on the black marlin are much less conspicuous than in the other species. On the first dorsal of the sailfish there are a large number of deep blue-black spots scattered irregularly.

(c) Head

On the head portion of the spearfishes the elongated jaws are the most marked characteristic.

The upper jaw of the broadbill is very long, broad, and flattened, so that in cross section it is an elongated ellipse. The length of the upper jaw measured from the posterior edge of the premaxillary exceeds 0.7 of the length of the body without the snout.

In the fishes of the family Istiophoridae the upper jaw forms a long slender cone, the length of which does not attain 2/5 of the length of the body without the snout. The length of the upper jaw is greatest in the striped marlin and least in the shortnosed spearfish, the proportions of length of the snout to the rest of the body in these two species being 2.804 and 6.278 respectively.

Marked differences can be detected among the species in the ratio between the lengths of the upper and lower jaws. In the broadbill swordfish the ratio is 4-1/4, while among the fishes of the family Istiophoridae it varies from 1.281 to 2.211, the shortnosed spearfish having the smallest ratio and the black marlin the largest.

The eminence extending forward from the origin of the first dorsal is not very conspicuous in the broadbill swordfish, but it is generally noticeable in the fishes of the family Istiophoridae, being most marked in the case of the white marlin and least developed in the shortnosed spearfish. This characteristic of the white marlin is shown by the fact that it is sometimes called "katahari" or "square shoulders."

The branchiostegal membranes or membrana branchiostega in the istiophorids are long and the left and right sides are joined, however, this fusion does not appear in the broadbill. The length of the branchiostegal membranes varies among the istiophorid fishes, being shortest in the black marlin, the gills of which can be seen between the branchiostegal membrane and the pectoral girdle. Consequently, differences in the length and form of the branchiostegal rays can also be seen.

(e) /sic/ Scales and lateral line

The broadbill swordfish has no scales and the surface of the body is smooth to the touch. Only the ventral surface in the pectoral region is rough with somewhat the feel of shark skin. The lateral line is not developed in the broadbill.

In the istiophorid fishes the scales are buried in the epidermis. They cover the whole body, but on the head they are to be seen only around the eyes and on the preopercle. The scales are very hard and strong and are elongated, the tips being pointed or forked, however, the scales

of the head have the form of a long ellipse. The lateral line is well developed and is curved upward conspicuously over the pectoral fins, posterior to which it runs in an approximately straight line along the center of the sides of the body.

(f) Fins

All of the fins except the ventrals are well developed in most families. The ventrals are not developed at all in the broadbill, and in the istiophorids they are represented by 1 to 3 thin rays. However, none of the fishes occurring around this island have ventrals composed of only one ray.

The first dorsal fin commences anterior to the posterior end of the cranium and the number of rays is 40 or more. The most anterior ones are spines, those in the longest portion of the fin are soft rays, their number being about 10, and posterior to these we again find spines. In the first dorsal of the broadbill the anterior spines and soft rays are remarkably developed, their height exceeding the body depth, but their length decreases rapidly posteriorly, and beyond about the 20th ray they are not developed outside of the body. In the Istiophoridae all of the rays of the first dorsal fin are developed outside of the body, but the greater part of the fin can be folded away into a sort of sheath which is developed along the dorsal surface.

Jordan and Evermann classified the istiophorids into genera based on the characteristics of the first dorsal fin as follows:

The dorsal fin of the shortnosed spearfish is not very high and its anterior lobe is small (genus Tetrapturus). In the black marlin, striped marlin, and white marlin of the genus Makaira the dorsal fin is low with a high anterior lobe and the anterior spines are thickened. In the sailfish (genus Istiophorus) the dorsal fin is very high and the ventral fins are very long with their rays fused together. Thus the dorsal fins of the Istiophoridae present various conspicuous characteristics.

The pectoral fins are very much developed, their length being only slightly less than the body depth (measured around the side of the body). The pectorals are smallest in the shortnosed spearfish. A groove in the side of the body into which the pectoral fins fit, such as is seen in the tunas, is not developed in the spearfishes. The structure of the pectoral fins of the white marlin is of a special type which differs from the other spearfishes. In the other fishes of both the family Istiophoridae and the Xiphiidae the pectoral fins can be pressed tightly against the sides of the body, but it is not possible to do so with the white marlin without breaking the joints between the pectoral girdle and the pectoral fins. For this reason it is very simple for us to find the white marlin among the spearfishes lined up in the fish market, one glance sufficing to show their location. Where a pectoral fin sticks out into the air at right angles from the body among a group of spearfishes, we know that it is a white marlin (see fig. 2).

The ventral fins are most developed in the sailfish and development is poorest in the white marlin, followed by the black marlin. The first anal fin is well developed in both families. In the Istiophoridae there is all along the base a sheath into which the greater part of the fin can be retracted. In the genus Makaira the first anal fin is almost identical in form to the anterior portion of the first dorsal, the first few rays being similarly thickened to a great degree.

The second dorsal and the second anal are well developed in the family Istiophoridae, each of them having 6 or 7 rays, but in the broadbill they are poorly developed and each have only 4 rays.

The caudal fin is very well developed in both families. In the broadbill the upper and lower lobes are both quite broad and the angle between them is rather small. In fishes of the family Istiophoridae both lobes are narrower than in the broadbill and the angle between them is large so that they are broadly forked.

2. Skeleton

Taking a general view of the skeleton, it differs conspicuously from the scombroid fishes, which are supposed to be most closely related to these species. The differences between the fishes of the families Istiophoridae and Xiphiidae are also remarkable, and it must be said that it is very difficult to compare and describe the skeletons of the fishes of these two families at the same time. Consequently I shall concentrate here on setting forth the comparisons among the fishes of the family Istiophoridae and will not touch in any detail upon the broadbill except in special circumstances.

(a) Cranium

There are no striking differences in the cranium. However, some differences are seen in the proportion of its length to its breadth. If the crania of these fishes are compared with those of the scombroids, striking differences can be seen. Most conspicuous, of course, are those differences based on the construction of the snout, which is a peculiarity of these fishes, but the thin processes on the supraoccipital which are found in the scombroids do not appear in these fishes, and the posterior projections of the epiotic and pterotic are conspicuous. In all of the species there are marked differences among individuals, so that it is difficult to determine the basic type (plate 3).

(b) Vertebrae

The vertebrae of the istiophorid fishes are very characteristic. The vertebrae of the fishes of this family and of the scombroids differ markedly both in form and in number. In the scombroids the number of vertebrae is fairly great, being from 38 to 50[11/]. In the istiophorids in all genera there are 24 vertebrae and both the neural spines and hemal spines are flattened into broad plates.

These flat plate-like neural spines are inserted into the neural processes of the succeeding vertebra so that they are strongly articulated together. The neural processes are modified into broad plate-like structures which extend far forward, so that the tips reach almost to the middle of the next most anterior vertebra. However, in the two most anterior vertebrae the neural spines are far narrower than the more posterior ones and are shaped more nearly like spines. The hemal spines are roughly the same shape as the neural spines and are strongly fused to the hemal processes of the neighboring vertebrae, just as are the neural spines and neural processes. Both the neural and hemal canals are very large (plates 4 and 5).

It is inferred from their form that the vertebrae of the istiophorid fishes are most unsuitable for precise movements and that sudden changes of direction are probably impossible. It is a well known fact that fishing boats are often attacked by spearfishes, but it is doubtful whether such attacks are made purposely. It may be that the fish strikes the boat because the construction of the vertebrae does not give it the ability to change its course in time.

These fishes of the family Istiophoridae, with 24 vertebrae, can be further divided into different groups. In the first group the vertebral count can be shown by the formula 12 + 12 and in the second group by the formula 11 + 13. Considerable differences in the form of the vertebrae can, of course, be detected among the species (plate 4), the proportion between the length and the height of the vertebrae differing in each species. The hemal spine of the first caudal vertebra differs markedly in form from those of the more posterior vertebrae and also differs among the species (see plate 5).

The above-mentioned two groups based on the vertebral counts have no connection at all with the presently recognized classification of the istiophorid fishes. The first group includes the shortnosed spearfish (Tetrapturus angustirostris), the sailfish (Istiophorus orientalis), and the

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[11/] Kishinouye, K., Jour. Coll. Agri. Tokyo Imp. Univ., Vol. 8, No. 3, 1923.

Plate 3.--Crania. A - shortnosed spearfish; B - white marlin; C - striped marlin; D - black marlin.

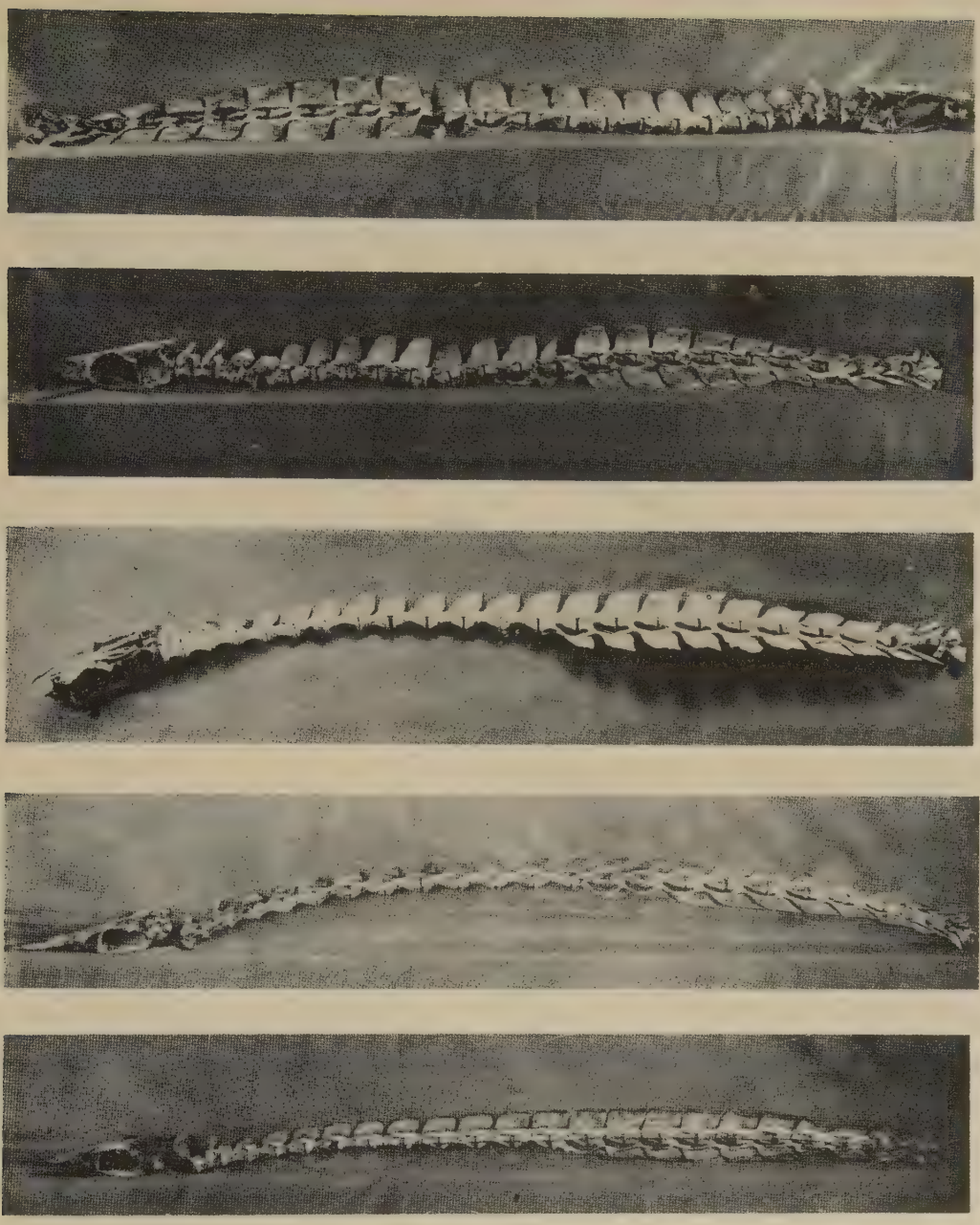


Plate 4.--Vertebrae. A - white marlin; B - black marlin; C - striped marlin; D - sailfish; E - shortnosed spearfish.

A

B

C

Plate 5.--A - membrane bones of the black marlin; B - structure of the vertebrae--from top to bottom, sailfish, broadbill swordfish, shortnosed spearfish; C - articulation of vertebrae (shortnosed spearfish).

striped marlin (Makaira mitsukurii), while the second group includes the black marlin (Makaira mazara) and the white marlin (Makaira marlina).

In the family Xiphiidae, that is in the broadbill swordfish (Xiphias gladius), the vertebrae differ markedly from those of the istiophorid fishes. Neither the neural nor hemal spines are modified into such flat plates; they present only a somewhat flattened spine shape. Both the neural and hemal processes are remarkably small and only slightly support their respective spines on the next anterior vertebra. The number of vertebrae is also remarkably different, with a total of 26, of which 16 are ventral and 10 caudal, the formula being 16 + 10.

(c) Jaws

In the istiophorids the elongated upper jaw is formed of the premaxillary, maxillary, and nasals. The nasals are joined to the frontal, but the union is very weak. The lower jaw is formed of the articular and the dentaries, but the left and right dentary bones are not joined together directly as in other fishes, there being at their anterior ends a triangular bony structure which forms the sharp tip of the lower jaw and into which the dentary bones are articulated.

The upper jaw is made up in large part of the premaxillary, the maxillary itself attaining only one-half of the total length. It is narrow and except for the point of articulation with the vomer it is of nearly the same thickness throughout. The nasals make up the dorsal surface of the upper jaw and extend over 3/4 of the total length. They are flat and gradually tapering and are fused to the premaxillary. The upper jaw is not hollow but is almost solid with a fibrous structure like that seen in chips of bamboo.

Both jaws are covered with tiny cone-shaped bony teeth, but these innumerable teeth do not grow from the jaws, nor are they attached to them. The overall appearance of these teeth is like a rasp, and they are somewhat coarser on the outer edges of both jaws and near the posterior end of the premaxillary. Of course, these teeth are probably of some use when the spearfish seizes its prey, but this objective alone does not suffice as a physiological and morphological explanation of these teeth for the reason that the teeth can be seen to exist near the tip of the upper jaw, which is far beyond the tip of the lower jaw.

There are conspicuous differences among the species in the ratio between the lengths of the upper and lower jaws as measured from the posterior end of the maxillary, this ratio being 2.21 in the black marlin, 2.19 in the sailfish, 1.94 in the white marlin, 1.84 in the striped marlin, and 1.28 in the shortnosed spearfish (see plate 6 and table 3).

In the broadbill, the upper jaw is made up of the premaxillary, maxillary, and nasals as it is in the istiophorids, but it is markedly different in form. The lower jaw is made up of markedly frailer articulars and dentaries than in the case of the istiophorids. There are no teeth in either of the jaws in adult fish.

The upper jaw is compressed, its dorsal surface flat and its ventral surface somewhat rounded, the ventral surface being composed of the left and right premaxillaries, which are solidly fused together. The dorsal surface is composed of the maxillary and nasals, all of which reach the whole length of the dorsal surface. All of these bones are solidly fused together so that it is difficult to separate them. Regan[12/] in his schematic diagram showing the structure of the upper jaw of the broadbill, has the nasals reaching only half way along the upper jaw, but it is thought that this point requires correction (figure 1). The upper jaw has a box-like hollow center with regular septa forming a ladder-like pattern, presenting the appearance of a longitudinally sectioned piece of bamboo.

12/ Regan, C. T., Ann. Mag. Nat. Hist. London, Vol. 3, No. 13, p. 73.

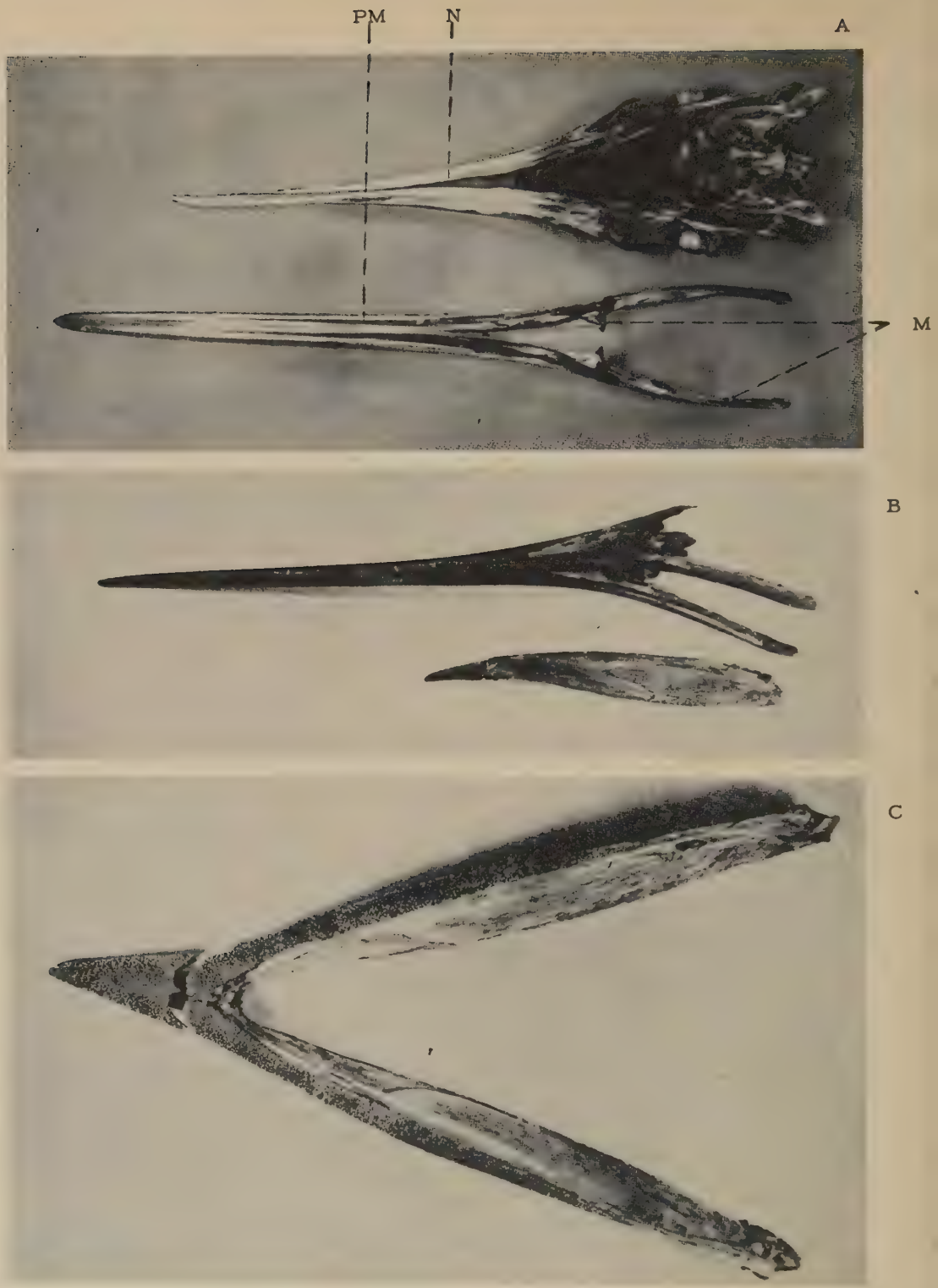


Plate 6.--A - structure of the upper jaw (striped marlin); N - nasals; M - maxillary; PM - premaxillary; B - both jaws (black marlin); C - lower jaw (black marlin).

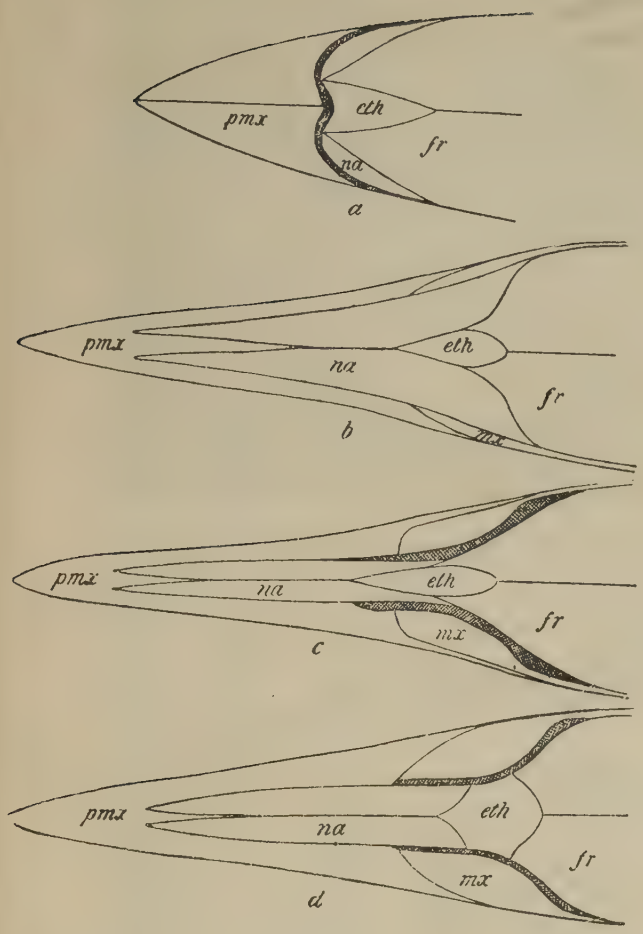


Figure 1.--Structure of upper jaw (from Regan). Diagram showing the structure of the rostrum in Acanthocybium (a), Histiophorus (b), Xiphias (c), and Xiphiorhynchus (d). pm premaxillary, mx maxillary, na nasal, eth ethmoid, fr frontal.

(d) Palatines

There are no remarkable differences in the overall form of the palatines among the istiophorid fishes. There are, however, remarkable differences in the teeth which grow on the palatines, the shortnosed spearfish having several rows of fine, sharp villiform teeth, whereas in the other species there are only one or two rows which are poorly developed or vestigial (plate 7).

(e) Posttemporal and supraclavicle

The anterior portion of the posttemporal is trident-shaped and articulates with the cranium. Its posterior end is generally rounded, but has a triangular projection which extends obliquely down and rearward.

In the white marlin the posterior edge is rather triangular, and in the very middle of the broadest portion of the bone there is a somewhat slanting, conspicuous ridge, the anterior end of which projects in the form of a spine. In the black marlin the posterior end is rounded and the triangular projection is sharp. The process in the center is blunt, but along the lower edge of the bone at the base of the lowest portion of the anterior projection there is another small projection. In the striped marlin the end of the bone is roughly rounded, the central projection is rather broad, and the triangular posterior projection is broad and very close to the main part of the bone. The central process is very conspicuous and there is a deep concavity directly below it. The small projection on the lower edge of the bone which was seen in the black marlin is also present in this species. In the sailfish the posterior part of the bone is markedly smaller and narrower than in the other species, the triangular projection is large, and the central process is obscure. There is no projection along the lower edge. In the shortnosed spearfish the posterior end of the bone is rather elliptical, the triangular projection is broad and large, and instead of the central process there is a somewhat oblique deep groove.

Some differences are also to be seen in the form of the supraclavicle. In general, this bone is spatulate in shape with its upper edge irregular and gradually sharpening and its lower edge rounded. The central portion of the bone is somewhat constricted.

In the white marlin the irregular upper end is rather long and twisted downward somewhat and the lower end is also irregular. In the black marlin the upper end is short and the lower end is nicely rounded, while the constriction of the central part is conspicuous. In the striped marlin the upper end is rather like that of the white marlin, the lower end is nicely rounded, and the central part is only slightly constricted. In the sailfish the upper end is short and the portion following it is rather expanded, the constriction of the central part is conspicuous, and the lower

A

B

Plate 7.--A - palatine bones and their teeth (black marlin); B - posttemporals and supraclavicles--from outside in, white marlin, black marlin, striped marlin, sailfish, shortnosed spearfish.

end is perfectly rounded. In the shortnosed spearfish the upper portion is the shortest among all the species and is somewhat rounded, and the constriction of the central portion is very obscure; the lower end is perfectly rounded. In the broadbill swordfish these bones are completely different in form and comparison is difficult (plate 7).

(f) Branchiostegal rays

Conspicuous differences among the branchiostegal rays of the various species can be seen. The number of these rays in both families of spearfishes is 7. In the white marlin the last ray is remarkably broad, short, and stout, with a roughly triangular form, the other rays being generally long and slender. In the black marlin, as has already been stated, the branchiostegal membrane is short, and consequently the branchiostegal rays are also markedly shorter than in the other species. In the striped marlin all of the branchiostegal rays are rather filamentous, they are even slenderer in the sailfish, and in the shortnosed spearfish they are the most filamentous of all (plate 8).

In the broadbill the epihyal is strikingly large, and the branchiostegal rays are flat and thin and conspicuously curved.

(g) Pectoral girdle

As was stated earlier, in the white marlin the pectoral fins have a special direction of movement and cannot be folded back against the sides of the body. It was thought that the reason for this was probably that the joint between the pectoral fins and the bones which support them was of a peculiar type or that there was some difference in the arrangement of the muscles.

In the white marlin the articulating surface of the supracoracoid which articulates with the actinotis is almost horizontal, markedly broader than in the other species, and somewhat twisted anterioposteriorly. The anterior margin of the clavicle has a slight concavity on top and only a slight convexity below, being almost straight. In the other istiophorids the articulating surface of the supracoracoid with the actinotis is rather oblique, narrow, and is not twisted anterioposteriorly. Except in the striped marlin, the anterior edge of the clavicle has a conspicuous concavity, but in the striped marlin it is straight and similar in form to that of the white marlin. Rather conspicuous differences between the white marlin and the other species can also be seen in the form of the hypocoracoid, the breadth of the shoulder girdle as a whole is greatest in the white marlin, and the space between the hypocoracoid and the clavicle is greater in this species than in any of the others. As for the form of the hypocoracoid, there is a process which originates at about the middle of its upper edge and which curves back running along the posterior edge. In the white marlin the origin of the process is conspicuously large, but the process as a whole is blunt and quickly becomes obscure. A roughly triangular projection on the upper rear edge of the hypocoracoid is turned noticeably upward in the white marlin and shortnosed spearfish.

In the other species of the family Istiophoridae the pectoral girdle is in general narrow and the space between it and the clavicle is small; the process discussed above is sharp and conspicuous and extends all along the edge of the bone. The upper rear edge of the coracoid /evidently hypocoracoid is meant/ is almost horizontal (plate 9).

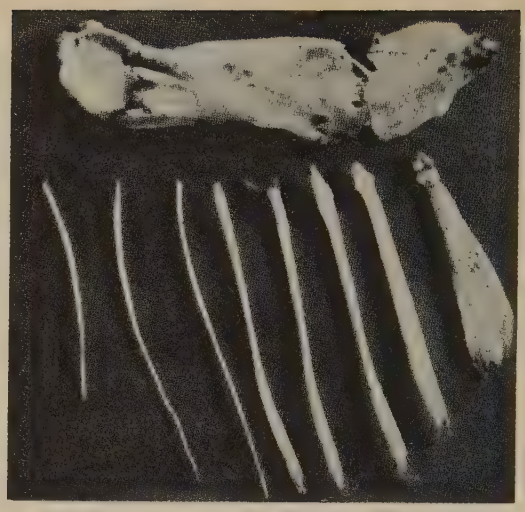
(h) Pelvic girdle and ventral fins

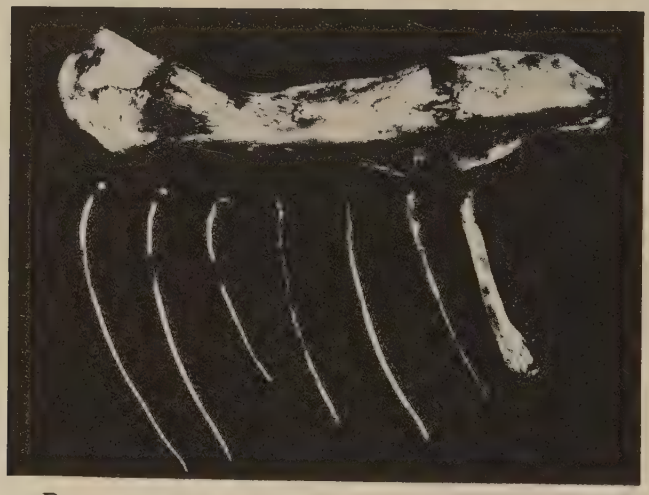
The pelvic girdle and ventral fins are lacking in the broadbill. In the Istiophoridae the pelvic girdle is well developed and is rather palmate in shape. Its structure falls into two types, of which one appears in the white marlin and the other in the rest of the species. As is shown in plate 9, in the former the right and left sides of the pelvic girdle are fused together and are difficult to separate, while in the latter type there is a broad space between the two sides and they can easily be separated.

Hitherto it has been considered that the number of rays in the ventral fins was 1 to 3 in the Istiophoridae with 1 in all species of the genus Tetrapturus and 3 only in the genus Istiophorus,

A

B





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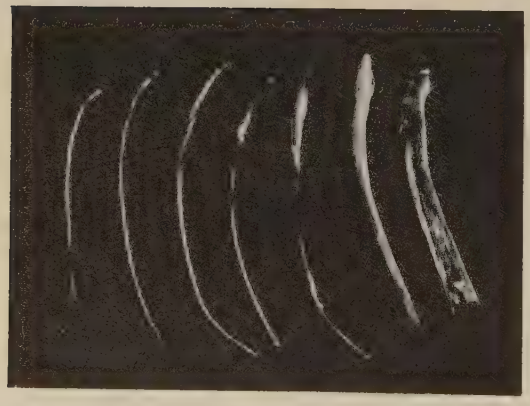


E

Plate 8.--Branchiostegal rays. A - striped marlin; B - white marlin; C - black marlin; D - sailfish; E - shortnosed spearfish.

A

B

C

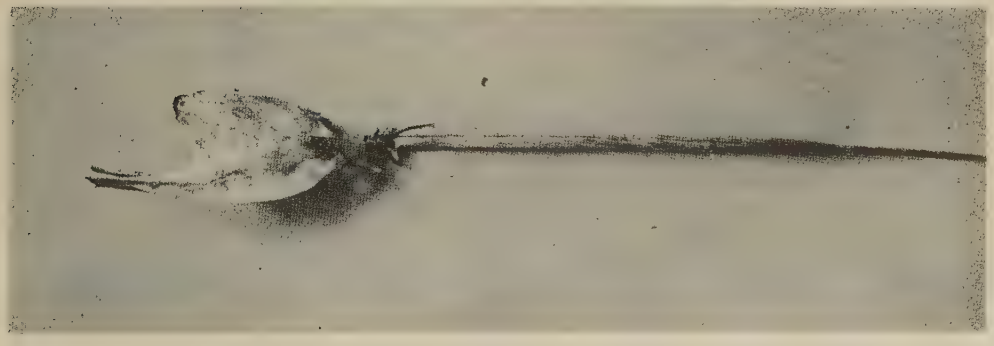


Plate 9.--A - shoulder bones. Top row from left to right: white marlin, black marlin, striped marlin; lower row from left to right: shortnosed spearfish, and sailfish. B - pelvic girdle. On the right: black marlin; on the left: white marlin. C - pelvic girdle and ventral fin rays (black marlin).

however, as a result of the examination of a large number of specimens it appears that this is probably in error, at least the fishes of the family Istiophoridae in Formosa all have 3 ventral fin rays (plate 9).

3. Viscera

In the fishes of the family Istiophoridae the body cavity is very long, extending posterior to the anus, and its posterior end reaches the area above the origin of the first anal fin. In the broadbill the body cavity is short and wide, and its posterior end is anterior to the first anal fin.

In the istiophorid fishes the anus is in an advanced position about the length of the first anal base anterior to the anterior end of that fin.

In the Istiophoridae the stomach is very large, in full specimens reaching almost to a point above the anus. The opening of the intestine appears close to the cardiac orifice and the intestine itself is slender, about the size of one's thumb, and enclosed in the pyloric caeca. This portion of the intestine is somewhat expanded; the intestine then makes a sharp bend, the portions adjacent to the bend lying parallel to each other, and it then makes a slight curve along the tip of the pyloric caeca after which it runs straight to the anus. The length is much less than the body length, the proportions being about 2.26. The contents of the intestine are simply mucus and it is not possible to discover any solid object with the naked eye. The liver is rather small and covers a part of the pyloric caeca, and the gall bladder is slender and elongated. In a general view this digestive system presents a form extremely close to that of the tunas.

The air bladder is very distinctive, being formed of many chambers like a mass of bubbles lying along the dorsal surface of the whole body cavity. The digestive organs and the gonads (except in the shortnosed spearfish) are all contained in the body cavity anterior to the anus, with only the air bladder extending posterior to the anus and reaching a point above the origin of the second anal fin. This is a point of conspicuous morphological difference between the istiophorid fishes and the scombroids, which are considered to be most closely related to them. The air bladder is composed of small chambers of irregular size, but the arrangement of these is more or less bilaterally symmetrical (plate 10).

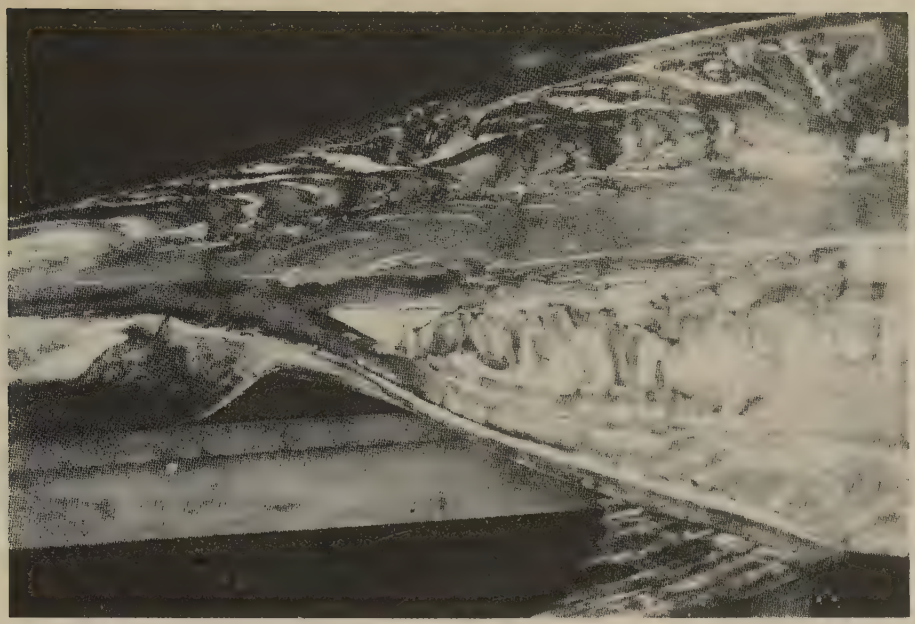
The gonads are on the whole bilaterally symmetrical, but in the shortnosed spearfish only they have a peculiar structure, being Y-shaped with the right side short and its posterior end joined to the left side. The point where the two gonads are joined is directly above the anus and they open through a single short reproductive duct. The left gonad is prolonged posteriorly and in well-matured specimens it reaches the posterior end of the body cavity.13/

The tip of the ureter is markedly expanded, forming a part which might be called a urinary bladder.

In the broadbill the body cavity is short and capacious and there is no marked difference from the istiophorid fishes in the structure of the digestive tract. The body cavity appears only anterior to the anus, the stomach is large, the liver is small, and the pyloric caeca are also markedly smaller than in the Istiophoridae. The form of the intestine is somewhat different, the flexed portion being notably shorter, and differences in thickness are apparent from the anterior to the posterior end. In the istiophorids a cross section presents a regular round shape, but in the broadbill it is irregular with conspicuous indentations and projections.

The air bladder is single-chambered and large. Its membranes are weak and it is easily destroyed.

13/ Nakamura, Hiroshi. Zoological Magazine, Vol. 49, No. 6, pp. 233-238, 1937.



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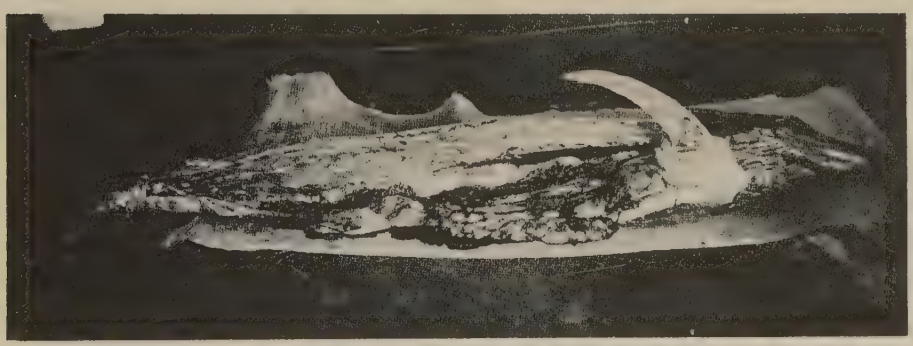

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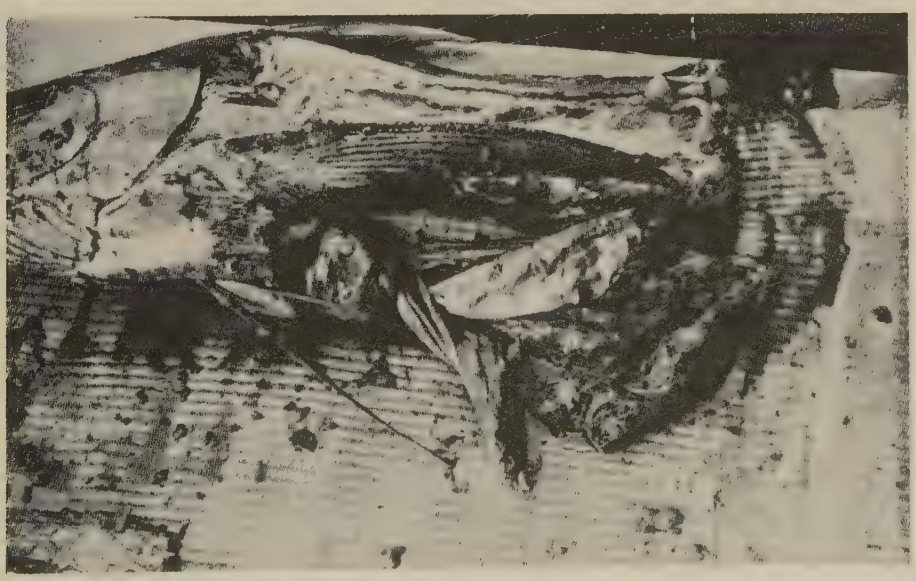

C

Plate 10.--A and B - showing structure of the air bladder;
C - natural food of the marlins (black marlin); the
stomach contents are mackerel.

C. Classification

Jordan and Evermann[14] have been taken as the standard for classification.

Classification of the families

a. Ventral fins present with 1 to 3 rays, scales developed, all rays of the dorsal fin externally developed even after maturity. Two pairs of keels of equal size on both sides of the caudal peduncle. Teeth very small and firmly attached, sword-shaped portion of upper jaw narrow and almost round in cross section. Left and right branchiostegal membranes fused together . . . . . Istiophoridae

b. Ventral fins absent, scales not developed. The most posterior rays of the first dorsal fin disappear after maturity. The caudal peduncle has a single pair of very large keels, and the teeth are lost after maturity. The sword-shaped portion of the upper jaw is broad and long and elliptical in cross section. The left and right branchiostegal membranes are not joined together . . . . . Xiphiidae

a. Family Istiophoridae

Classification of the genera

a') Dorsal fin not remarkably high, anterior lobe small, whole dorsal fin well developed. Body slender, upper jaw short, no spots on sides of the body. Ventral fin somewhat developed . . . . . Tetrapturus

a'a') Dorsal fin remarkably developed, ventral fins long, snout long, body slender with spots on the sides . . . . . Istiophorus

a'a'a') Dorsal fin low, its anterior lobe large, anterior spines stout. Ventral fins generally poorly developed, body stout, spots may be present or absent on the sides . . . . . Makaira

Genus Tetrapturus Rafinesque*, fūraikajiki genus

Jordan and Evermann record six species for this genus, five of them from the Indo-Pacific region. However, those taken in Formosa all belong to the following single species.

1) Tetrapturus angustirostris Tanaka, fūraikajiki /shortnosed spearfish/

Plate 13, figure 1 (no Formosan name)

Tetrapturus angustirostris --Tanaka, Shigeo. Japanese Ichthyology, p. 375, 1921.

Tanaka, S. Fishes of Japan, 1, 2d edition p. 324, 1935.

Jordan and Evermann. Occ. Papers Calif. Acad. Sci. XII, p. 31, 1926.

Morphology - D. III, 11-13, XXXV-XXXVII, 6. A. II, 12., 7. V. I, 2. Vertebrae - 24 (12 + 12)

Body slender and not very large, specimens over 20 kg. being rare. Body length 6.88 times body depth (measured around the sides of the body), 7.9 times body depth at the origin of the first anal, and 6.28 times the length of the snout. Length of snout 1.39 times head length

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[14] Jordan and Evermann. Occ. Papers Calif. Acad. Sci., XII, 1926.

* Rafinesque. Caratteri di alcuni nuovi generi e nuove specie di animali e piante della Sicilia, 1810.

without the snout, the latter being 3.33 times the eye diameter. Upper jaw slender and short, its length being 1.28 times the length of the lower jaw (both jaws being measured from the posterior end of the maxillary). The first dorsal is well developed, with its anterior lobe low, its central portion rather higher, and its rays filamentous. The rays of the dorsal fin are described by Dr. Tanaka as being all soft rays and by Jordan and Evermann as being all spines, but the result of dissection, as shown above, is that the 3 most anterior are spines, the following 8 to 9 are clearly soft rays with branched tips, and the remaining more posterior ones are again spines. The pectoral fins are comparatively short, being 0.86 times the body depth (measured as above and likewise in subsequent references). The ventral fins are represented by three rays and they are moderately well developed. The anus is located anterior to the first anal fin, from which it is separated by a distance roughly equal to the length of the base of that fin. The second dorsal and second anal fins are of approximately the same shape and size. Along the bases of the first dorsal and first anal fins are developed grooves in the skin in which these fins can be accommodated. The caudal fin is broadly forked, both lobes are narrow, and there are two pairs of keels on the peduncle. The body has a steely color on the back, the belly is silvery white, and the boundary between these two colorations is comparatively well marked and runs somewhat dorsal of the center of the sides of the body in an approximately straight line with small serrations along the boundary. There are no markings on the sides of the body. The lateral line is clearly apparent and forms rather complex curves anteriorly while in the posterior part it runs almost straight along the center of the sides of the body.

The upper and lower jaws have rasp-like teeth, and there is a broad area of sharp, long teeth on the palatines. The cranium is rather narrow and the vertebrae are rather delicate, there being 12 ventral and 12 caudal vertebrae.

The gonads have a characteristic form, being Y-shaped as a whole, the left side being remarkably developed and extending far posterior beyond the anus. In mature ripe specimens the left gonad together with the air bladder reach to the vicinity of the posterior end of the body cavity. The right gonad is small and is joined to the left one in the vicinity of the anus with the reproductive duct attached at the point of juncture. In the male the posterior portion of the left gonad is poorly developed so that the gonads form roughly a V-shape.

Habits

This species has hitherto been so rare in Formosa that it had no particular name, but through the fishing experiments of the Formosan Government-General's fishery research vessel Shōnan Maru from October to December of 1935 and from October to December 1936 it was found that the species occurs in rather dense concentrations far off to the east of the island (30 to 300 miles off shore) in the area of the Japan Current, and at the same time it was learned that it spawns in that area at this season.

Genus Istiophorus Lacépède*, bashōkajiki genus

Nine species are recorded for this genus, five of them from the Indo-Pacific region; only one species is known from Japan and only one from Formosa. Its study was undertaken with particular care because it was thought that there was ample possibility of the fishing vessels based at Takao taking some other species, since they fish on far southern grounds, however, none was found in the catch other than the same species found in Japan. It is thought that the three genera and 31 species of Istiophorus recorded by Jordan and Evermann may perhaps be reduced to a far smaller number of species through detailed studies. Only the following single species occurs in Formosa.

2) Istiophorus orientalis Temminck and Schlegel, bashōkajiki /sailfish/; basho, baren (throughout the island); Formosan names 雨傘魚 (Keelung), 雨傘旗魚 (Suō).

Plate 13, figure 2

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* Lacépède. Hist. Nat. Poiss., III, 274, 1803.

Istiophorus orientalis --Tanaka, Shigeo. Japanese Ichthyology, p. 373, 1921.

Tanaka, Shigeo. Illustrated atlas of useful, harmful and admirable aquatic animals and plants, 1933.

Jordan and Evermann. Occasional Papers, Calif, Academy of Sci. XII, page 46, 1926.

Morphology - D. III, 9, XXXII-XXXV, 6-7. A. II, 11, 6. V. I, 2.
Vertebrae-24 (12 + 12)

Body length 3.19 times head length, body depth 6.3 times body depth (a), 7.8 times body depth (b); head length 1.40 times snout length and 7.6 times interorbital space.

(a) Regular body depth.
(b) Body depth at the origin of the 1st anal. Subsequent references to body depth will be to this measurement.

The length ratio of the jaws measured from the posterior end of the maxillary is 2.19, and the ratio of snout length to the length of the head without the snout is shown by 2.83. The body is conspicuously compressed in the anterior part, but in the caudal region it becomes almost cylindrical. There are two pairs of keels on the caudal peduncle. The 1st dorsal fin is greatly developed and high and has rather strong spines in its anterior portion. The length of the 3rd spine is slightly more than 1.3 times the body depth. The 1st dorsal fin profile is high in front and gradually curved in a concave shape after which there are again very long large spines dropping off gradually in the form of an arc to the end of the fin. The pectoral fins are well developed, their length being 1.1 times the body depth. The ventral fins are the most highly developed among the istiophorid fishes, their tips extending approximately to the anus. The second dorsal and the second anal are approximately the same shape; the number of rays in the former is 6 to 7, in the latter 6. The caudal fin is greatly developed; its upper and lower lobes are long and narrow and meet at a large angle. The dorsal surface is a deep purple black and the belly is brownish. There are more than 10 transverse bands of cobalt spots on the sides. Black spots the size of soy beans are scattered over the 1st dorsal fin. The vertebral formula is 12 + 12 and all of the vertebrae are long. The rasp-like teeth are developed in both jaws, but the teeth on the palatines are poorly developed and vestigial, and there is only one row of them.

Among past reports of the ray counts for the dorsal and anal fins, Dr. Tanaka gives 44 soft rays for the 1st dorsal, 6 rays for the 2nd dorsal, 10 soft rays for the 1st anal, and 6 soft rays for the 2nd anal, while Jordan and Evermann give 41 for the dorsal. The results of the author's study differ quite markedly from these, but since there are no other important morphological differences this fish is considered to be the same species as Istiophorus orientalis of Japan proper. Hitherto the ventrals have been considered to have only one ray, however, it has been ascertained by dissection that this is an error and it should be corrected to 1 spine and 2 soft rays. The second dorsal fin has 6 to 7 rays, 7 in most specimens, with 6 fish out of a sample of 8 having 7 rays in the fin.

Habits

The seasons of migration of this species are completely different from those of the other istiophorid fishes. It is most abundant in the waters adjacent to the island in the summer and characteristically approaches very close to the coast. Unlike other species, the catch remains comparatively high throughout the year. The juveniles are remarkably phototropic and are often taken as they congregate around a night light. The fish which migrate into the waters around the island in the summer have rather highly developed gonads.

Genus Makaira Lacépède*, makajiki genus

All of the most important spearfishes in Formosa are included in this genus. Of the 16 species known throughout the world, 3 appear in Formosan waters.

Key to the species

a'' Pectoral fin can be placed parallel against the side of the body, markings on sides of the body.

a''' Pectoral fins large and long, dorsal fin high, body rather conspicuously compressed laterally, length of upper jaw does not attain twice the length of the lower jaw. . . . . striped marlin or red marlin (makajiki or akajiki)

a'''a''' Pectoral fins long and large, dorsal fin rather low, degree of lateral compression of body not marked. Body very much rounded in the vicinity of the first anal fin, length of upper jaw more than twice length of lower jaw. ... black marlin (kurokajiki or kurokawakajiki)

a''a'' Pectoral fins form a right angle with side of the body and cannot be folded back against the body without breaking the joint; no markings on the sides of the body. . . . . white marlin (shirokajiki or shirokawakajiki)

3) Makaira mitsukurii Jordan and Snyder, makajiki /striped marlin/

Plate 14, figure 1

Akakajiki or aka (Suō, Keelung, Takao); Formosan names 紅肉旗魚 or 紅肉丁版 (Keelung).

Tetrapturus mitsukurii -- Jordan and Snyder. Jour. Coll. Sci. Imp. Univ. Tokyo, 1901.

Tanaka, Shigeo. Japanese Ichthyology, p.374, 1921

Tanaka, Shigeo. Illustrated atlas of useful, harmful, and admirable aquatic plants and animals, p. 163. 1933.

Makaira mitsukurii--Jordan and Evermann. Occ. Papers Calif. Acad. Sci. XII, 1926.

Morphology - D. III, 12-15, XXII-XXV, 6. A. II, 12-13, 6. V. I, 2. Vertebrae- 24 (12 + 12)

The body appears rather conspicuously compressed laterally in the anterior portion and becomes almost cylindrical in the caudal portion. The body depth is rather small and diminishes at a remarkably high rate to the origin of the first anal fin. Body length is 2.6 times the head length, 5.23 times the body depth (a), and 6.9 times the body depth (b). The head length is 1.5 times the snout length and 6.12 times the interorbital space. The length of the upper jaw is 1.85 times the length of the lower jaw, and the ratio of the snout to the rest of the body is 2.80. The distance from the eye to the origin of the 1st dorsal fin is 4.1 times the eye diameter. The body depth is 4.9 times the caudal peduncle, which is a remarkably small ratio compared to the other fishes of the genus Makaira. The dorsal fin is well developed, its anterior lobe is high, and the posterior portion is much better developed than in the other species. The height of the first dorsal is approximately equal to the body depth; the pectorals are greatly developed, their length exceeding the body depth, which is in the proportion of 0.95. The anal fin is also well developed, and the caudal fin is of normal form.

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* Lacépède. Hist. Nat. Poiss., IV, 683, 1803.

The vertebral count is 24 (12 + 12), differing from the other species of the genus Makaira, which have 11 + 13. The palatine teeth are vestigial and the branchiostegal rays are slender. In life the dorsal surfaces are dark purple in color and the ventral surfaces are silvery white. There are no markings other than a dozen or so clearly apparent transverse cobalt bars on the sides of the body.

This is the smallest and the highest priced fish of the genus Makaira.

Habits

This fish is very abundant around the island throughout the whole fishing season, and it is occasionally but rarely taken in fixed gear in the summer. It is present in greater or lesser numbers around the island throughout the year. Those taken during the winter at distances from 30 to 300 miles off the coast are generally very small, large ones being taken in the coastal zones within 30 miles.

4) Makaira mazara Jordan and Snyder, kurokajiki /black marlin/

Plate 13, figure 2

Kurokajiki or kurokawakajiki (throughout the island); Formosan names 烏(黑)皮旗魚 (Suō), 鐵皮丁版 (Keelung).

Tetrapturus mazara--Jordan and Snyder. Jour. Coll. Sci. Imp. Univ. Tokyo, 1901.

Tanaka, Shigeo. Japanese Ichthyology, p. 375, 1921. (kurokawa) Asano, Kōtaro. Illustrated classification of aquatic animals, 1933.

Tetrapturus mitsukurii (?)--Tanaka, Shigeo. Illustrated atlas of useful, harmful, and admirable aquatic animals and plants, p. 163, 1933.

Makaira mazara--Jordan and Evermann. Occ. Papers Calif. Acad. Sci. XII, p. 53, 1926.

Morphology - D. III, 14-16, XXIII-XXVII, 7. A. II, 14, 7. V. I, 2. Vertebrae-24 (11 + 13)

The body is not as compressed laterally as in other species but is rounded, the body depth increasing somewhat in the vicinity of the 1st anal fin. Body length is 2.76 times the head length, 4.56 times the body depth (a), and 5.68 times the body depth (b). The head length is 1.53 times the snout length, 5.7 times the interorbital space, and the distance from the upper posterior edge of the eye to the origin of the 1st dorsal fin is 4.22 times the eye diameter. The upper jaw is 2.21 times the length of the lower jaw, and the ratio of the snout length to the rest of the body is 2.97. The body depth (a) is 5.9 times that of the caudal peduncle. The anterior part of the 1st dorsal fin is well developed, but it gradually becomes lower posteriorly; the anterior fin rays are stout. The body depth is about 1.5 times the height of the 1st dorsal. The body depth is 1.2 times the length of the pectorals, which are well developed. The ventral fins are poorly developed and small. The anal fin is well developed. The caudal fin is broadly forked, and both its upper and lower lobes are narrow. The caudal peduncle bears two pairs of keels, an upper and a lower. The dorsal surfaces of the body are dark purple, the ventral surfaces are brownish, and the body as a whole has a conspicuously blackish tinge which gives it its name kurokawakajiki or "black skin spearfish." In life the dorsal fin is a beautiful cobalt color, but it turns black if exposed for long to the air. The sides of the body have obscure transverse bands made up of cobalt spots, the spots running together. The lateral line is rather complexly curved in the anterior portion, but the posterior part runs straight.

The vertebral count is 11 + 13, both jaws have rasp-like teeth, and the palatine teeth are poorly developed and vestigial. The pectoral girdle is narrow and its anterior margins are conspicuously concave. The branchiostegal membranes are short and the branchiostegal rays are

small. The Japanese name of this species was formerly given as mazara, but since it is generally called kurokawa or kurokajiki, I have assigned it the common name kurokajiki as being more suitable.

Habits

This fish is much less common in Formosan waters than the other species, however, the catch increases somewhat around the fishing season, that is, in February and March. The results of the work of the Shōnan Maru in the East Philippine Sea, June to August 1937, showed that this species is very plentiful there at that season. There is also at this season a great disparity in the sex ratio, females being extremely rare.

5) Makaira marlina (Jordan and Evermann) white marlin, shirokajiki (new name)

Plate 15, figure 1

Shirokawakajiki or shiro (Suō, Keelung, Takao), katahari (whole island); Formosan name 立翅旗魚 (Suō).

Makaira marlina--Jordan and Evermann. Occ. Papers Calif. Acad. Sci. XII, p. 59, 1926.

Tetrapturus mitsukurii (?)--Tanaka, Shigeo. Illustrated atlas of useful, harmful, and admirable aquatic animals and plants, p. 163, 1933.

Morphology - D. III, 10-12, XXIII-XXV, 7. A - II, 10-11, 7. V - I, 2. Vertebral count-24 (11+ 13).

Body very stout, gigantic specimens are not unusual. The dorsal profile anterior to the first dorsal fin, where the body depth is greatest, projects conspicuously, for which reason the fish has the name of katahari (square shoulders).

The body length is 2.17 times the head length, 4.46 times the body depth (a), and 5.85 times the body depth (b). The head length is 1.52 times the snout length and 5.75 times the interorbital space. The length of the upper jaw is 1.95 times the length of the lower jaw. The upper jaw is short, the proportion of the length of the head minus the snout to the snout length in this species being 3.14. The distance from the eye to the first dorsal fin is 4.33 times the eye diameter. The caudal peduncle tapers down sharply and the ratio between its depth and the body depth is 6.12. The development of the dorsal fin is inferior to that in other species, the ratio to the body depth being 1.61. A number of the most anterior rays of the fin are conspicuously thickened, and because the more posterior rays diminish in length sharply, the fin presents a conspicuously falcate shape. The pectoral fins are quite well developed, and because they stand out from the sides of the body at a right angle, they have gained for the fish the Formosan name of "erect wing spearfish." The proportion of the length of these fins to the body depth is 1.14. The ventral fins are very small. The first anal fin is suitably developed, as are the second dorsal and the second anal, both of which have 7 fin rays. The caudal fin is of a normal shape, and there are two pairs of projections, an upper and a lower, on the caudal peduncle.

The vertebral count is 24 (11 + 13), and the palatine teeth are quite vestigial. The more anterior branchiostegal rays are long and slender, but the more posterior ones are markedly thickened, the most posterior ray being almost triangular in shape. The pelvic girdle, unlike those of other species, has the right and left sides fused together so that they are difficult to separate. The pectoral girdle is broad and has a peculiar form. The upper jaw is somewhat broader than in other species and is flattened so that its cross section is elliptical.

In life the dorsal surfaces are steel blue and the belly is white, and before the slime has dried the body as a whole presents a rather milky white color, accounting for the name "white-skinned marlin." The dorsal and anal fins are a clear cobalt blue, the pectorals and the caudal fin are dark purple, and there are no markings of any sort on the sides of the body. In fish which

have been exposed to the air for a long time and from which the slime has completely been removed, the dorsal surface is sometimes seen to show vestigial pale transverse bands.

Habits

This species is the most abundant around this island, being particularly numerous early in the fishing season. Its distribution appears to be comparatively restricted to coastal areas and it is rather rare off shore. At times when the direction of the wind changes suddenly and the monsoon begins to blow strongly, there appears to be a particular increase in the number of these fish rising to the surface, and during such weather the spearfish catch of the harpoon boats is usually made up almost entirely of this species.

The Makaira marlina recorded by Jordan and Evermann was based on a photograph and can hardly be said to be satisfactory. Its distribution is given as the Pacific coast of Mexico from Cape San Lucas south. In its skeleton and in its form this species differs conspicuously from the other species of the genus Makaira, particularly marked differences appearing in the construction of the pectoral fins, the form of the pectoral girdle, and the morphology of the pelvic girdle. It may even be thought proper to establish a separate genus in which to place this species. It is the author's intention to take up this point when further studies have been carried out in the future. This is a new species for Japan. In accordance with the usage of the commercial fishermen I have given it the name shirokajiki or white marlin.

Family Xiphiidae, mekajiki family

This family has one genus with one species, which is universal in distribution.

6) Xiphias gladius Linné, mekajiki /broadbill swordfish/. Tsun (Suō, Keelung, Takao); Formosan names 丁版舊旗魚 (Suō); 白肉丁版 (Keelung).

Plate 15, figure 2

Xiphias gladius-- Jordan and Evermann. Occ. Papers Calif. Acad. Sci. XII, p. 71, 1926.

Tanaka, Shigeo. Japanese Ichthyology, Vol. I, p. 375, 1921.

Morphology - D. III, 9, XXVI, 4. A. II, 7, IX-X, 4. Vertebrae-26 (16 + 10)

Body approximately cylindrical, snout very long, one pair of large keels on the caudal peduncle. Caudal peduncle somewhat flattened horizontally. The body length is 1.85 times the head length, 5.18 times the body depth (a), and 5.92 times the body depth (b). The ratio of the lengths of the upper and lower jaws is 3.79, and the head length is 8.69 times the interorbital space. The dorsal fin is high, being in the ratio of 1.07 with the body depth, and the pectoral fins are short, being in the ratio of 1.32 with the body depth. The second dorsal and second anal fins are small, the caudal fin is large with both its upper and lower lobes rather broad and their angle small; the ventral fins are lacking.

The upper jaw is hollow in the center; the maxillary, premaxillary, and nasals are all strongly fused together and all reach to the tip of the snout. The form of this snout differs strikingly from that of the fishes of the family Istiophoridae. The form of the rest of the skeleton is also completely different, so that comparison with the istiophorid fishes is difficult. The body cavity is short and spacious, and the air bladder is single-chambered and large.

The coloration is a dark blackish brown on the dorsal surface and rather yellowish on the ventral surface. The boundary line between these two types of coloration is not as well marked as it is in the istiophorid fishes, the color of the dorsal surface gradually fading into the color of the ventral surface. There are no scales on the body, only the skin on some parts of the pectoral region having a feeling like sharkskin to the touch.

Habits

The life history of this species is known, but in Formosa it is not possible to acquaint oneself with it. In general this species is rather rare in Formosa, an occasional one being landed at Takao. It is thus not an important species. It appears that in the waters off eastern Formosa it is taken only extremely rarely and is not an objective of the harpoon fishery but is taken by the longline fishery. According to conversations with experienced fishermen, when this species is hooked and dies in the water it immediately floats to the surface and does not sink like the other spearfishes.

II. ECOLOGY

A. Migrations

There are a great many things that are not known about the habits of the spearfishes. Here I will deal chiefly with the migrations of the spearfishes in Formosan waters.

In the conduct of such a special sort of fishery as the harpoon fishery, the habits of the spearfishes are skillfully utilized. When the wind and waves are high, the spearfishes rise to the surface of the water and swim there with their dorsal fins projecting. According to experienced fishermen, this surfacing of spearfish is most often seen when the current and the wind are running in exactly opposite directions, and no fish are seen at the surface at all when the current and the wind are running in the same direction. It is said that in many cases the direction in which surfaced spearfish swim coincides with the wind direction and runs counter to the direction of the current. However, this does not mean that when such conditions prevail the spearfishes are at the surface all of the time; it is said that they come up temporarily, and that when they begin to come up they all come up at once.

In the waters off eastern Formosa, where the Japan Current passes, the current flows north with a slight easterly component. From October to March the northeast monsoon blows quite continuously in a direction just opposite to that of the current, and if we are to adopt the results of the fishermen's experience, this sea area must be said to be a well-suited ground for spearfish fishing.

Judging from the results of several years of commercial fishing experience, in the winter the normal distribution of atmospheric pressures breaks down and weak lows arise or pass through the waters north of Formosa, and at such times the monsoon stops blowing, there are light southerly winds, and the sea surface becomes calm and the sky clear. In such weather the commercial boats stay in port and give up going fishing. Such weather ordinarily continues for 1 to 3 days, and as the lows move away and dissipate, strong high pressures appear in the Mongolian region, and with the return to normal of the distribution of atmospheric pressure, the wind direction changes suddenly and the monsoon begins to blow strongly. When there are these sudden shifts in the wind direction, the spearfishes come to the surface in the greatest numbers and many specimens much larger than those ordinarily caught are taken, the white marlin appearing to be most numerous among them. The fishing boats usually leave port before dawn and return in the evening, but in cases where the boats have failed to go out fishing because the light southerly winds were blowing before dawn (these winds are called "maji" or "maze"), if there is such a sudden change in the weather they will go out at any hour and it not infrequently happens that they make big catches.

The spearfishes are probably present in Formosan waters at all times of the year, but there is no doubt that the fact that they are particularly abundant at certain seasons is due in large measure to seasonal changes in oceanographic conditions. However, the fact that they remain throughout approximately half of the year, forming dense schools in the waters off eastern Formosa, is difficult to account for simply by the direct effect of oceanographic changes.

The fishing season for spearfishes begins in the south and moves gradually north, usually ending around March or April in the vicinity of Hōkasho. We have the following oceanographic data for this area:

Table 3.--Water temperatures and specific gravities on the line from Suō to Yonakuni Island (averages from the surface to the 100 m. level; the underlined figures are at the height of the fishing season)

Months	Water temperatures	Specific gravities
1	22.7	25.67
2	22.7	25.80
3	22.6	26.00
4	23.3	25.98
5	24.3	25.79
6	25.3	25.98
7	26.1	25.82
8	26.2	25.79
9	26.4	25.35
10	25.6	25.69
11	25.0	25.69
12	24.2	25.87

Table 4.--Regular station observations at Hōkasho (1935)

Months	Water temperatures	Specific gravities
1	17.38	25.18
2	19.43	25.35
3	19.30	25.47
4	23.70	25.21
5	23.23	25.07
6	26.62	24.38
7	27.37	24.14
8	26.73	24.83
9	25.32	24.75
10	24.15	24.65
11	21.85	24.79
12	21.08	25.40

Table 5.--Regular station observations at Shinkō (1935)

Months	Water temperatures	Specific gravities
1	22.0	25.31
2	23.5	25.24
3	23.9	25.64
4	25.0	25.47
5	26.4	25.62
6	27.0	25.33
7	27.9	24.62
8	26.4	24.40
9	27.2	24.50
10	26.8	25.37
11	25.2	25.62
12	23.2	25.62

Table 6.--Regular station observations at Garanbi (1935)

Months	Water temperatures	Specific gravities
1	21.6	23.58
2	23.5	23.60
3	23.1	23.62
4	25.2	23.05
5	26.9	25.57
6	27.3	23.84
7	27.7	24.14
8	27.5	23.51
9	27.4	24.07
10	27.0	20.93
11	25.1	22.22
12	22.9	23.52

Among the foregoing oceanographic data, the figures for the line from Suō to Yonakuni Island are averages for the past 12 years. In general, the waters east of Taiwan ordinarily show high specific gravities in the winter and low specific gravities in the summer, but the changes are not regular as they are in the case of the changes in water temperature. The spearfishes are said to swim in comparatively shallow layers of the sea, and the construction of the air bladder is suitable for this. At Hōkasho there is comparatively little influence from the mainland so that the water temperatures and specific gravities observed there should not differ greatly from those of the waters farther off shore. It must be said that on the basis of these oceanographic data it is difficult to give an accurate explanation of the presence of the spearfishes during half the year in the waters east of Formosa. Consequently, it is difficult to explain the migrations of the spearfishes in terms of the direct effect of seasonal changes.

As will be set forth in a later section, it is clear that, except in the case of the sailfish and the shortnosed spearfish, the spearfishes which migrate into Formosan waters do not do so with the objective of spawning.

It being thus difficult to account for the migration of spearfishes in Formosan waters as being controlled by spawning or seasonal changes, it is necessary to consider some other cause. This cause, which, of course, will be subject either directly or indirectly to seasonal effects, is that at this season in this area the fishes upon which the spearfish feed are present in abundance. From October to March great schools of scad and mackerel are scattered through the waters east of Taiwan. The mackerel in particular form a great concentration from the Suō banks to the Kisantō region, and during the peak season of February and March they are taken in very large quantities by longline boats based at Suō, the catch for one day not infrequently exceeding 100,000 fish. According to the statistics for 1934, the yearly catch amounted to 2,477,600 kin with a value of 115,459 yen. These mackerel are not only in themselves an important objective of a fishery, but they are also utilized as bait for the longline fishery, and it is thought that they also play an important role in keeping the spearfishes in this sea area over a long period of time. It is known that if we investigate the stomach contents of the spearfishes taken during this fishing season, they are almost completely made up of mackerel (see plate 10).

The species which have been known to occur around this island since ancient times are the sailfish, white marlin, black marlin, and striped marlin, and the broadbill swordfish, little having been known about the distribution of the shortnosed spearfish. It was in 1935 that it became known that the shortnosed spearfish also occurs in the vicinity of this island. In investigations carried on in that year from October to December by the research vessel Shōnan Maru of the Taiwan Government-General, two shortnosed spearfish were taken in the waters east of the island. It thus became clear that this species also occurs in Formosan waters. Investigation was made to find out whether they were ever landed in the various markets, and it turned out that they were

only very occasionally brought into Suō. It was found out that there was no name applied to this species and that in the market they were handled as if they were sailfish. From October to December of 1936 the same vessel carried out another investigation of the same sea area and took 26 specimens of this species. The research vessels Shichisei Maru of Taihoku Province and Takao Maru of Takao Province, carrying out cooperative investigations in the sea areas to the north and south, also took several specimens of this species, so that its distribution was gradually clarified.

There are no essential differences between the longline gear used by research vessels and that used by commercial fishing boats, nor does it seem likely that the bait used is so different as to cause a difference in the catch. Consequently it must be thought that the fact that this species is not taken by commercial fishing boats but has been taken only by research vessels is due to the fact that they operated in different sea areas. Actually, the research vessels fished from 30 miles to 300 miles off shore but principally at about 150 miles off the coast, while the operating area of the commercial boats is restricted to a range of 30 miles from shore. Consequently we can conclude that the shortnosed spearfish occurs only in the far off shore waters. Furthermore, as the vessels get farther off shore they catch fewer of the large fish that are taken along the coast, and even most of the fishes of the genus Makaira that they take are very small. The following table gives statistics on the spearfish catch by months and by species for the Suō market in 1934 and 1935.

As is clear in the following table, in the waters east of this island the migrations of the spearfishes, except for the sailfish, are entirely limited to the winter monsoon, while the sailfish is taken throughout the year and is always present around the island, although it is more abundant in the summer. As will be detailed later in the section on the fisheries, from April to July everywhere on the east coast of Taiwan a large number of large set nets are used. The manner of using these set nets differs from place to place, but because on the east coast of Formosa the bottom falls off steeply the nets are placed very close to the shore. Sailfish are occasionally taken in these set nets. Very rarely a striped marlin is also found among the catch of the set nets, but for the most part the only spearfish they take is the sailfish. Consequently it is thought that the sailfish has the habit of coming in very close to the coast. Other fisheries also take considerable numbers of this species in the summer, a fact which it can be thought shows that the distribution of this fish in the waters around Formosa differs completely from that of other species in that it is comparatively densely present in the summer.

If we look at the statistics for several years' landings of spearfishes in the Suō market, we can see a tendency for white marlin to predominate overwhelmingly in the early part of the season, with striped marlin increasing gradually in the middle of the season until they equal the white marlin in numbers, and with black marlin appearing in large numbers at the end of the season. The appearance of the black marlin is for only a very short period of time, the striped marlin's season is next shortest, and the fishing for white marlin continues over a rather long time. Sailfish appear in considerable numbers comparatively abundantly throughout the year. According to the investigations of the Shōnan Maru from June to August of 1937, at this season large numbers of black marlin were taken in the Kuroshio Current area of the East Philippine Sea, and it is interesting to note that among the fish taken over 80 percent were male, females being very rare in the catch. Furthermore, the gonads of both the females and males were very immature. The larger fishing boats based at Takao operate in the vicinity of Hainan Island from April to June fishing longlines for black marlin, and it is reported that among the fish taken on this fishing ground there are not a few which have their gonads completely developed and are engaged in spawning.

To summarize, if we consider the occurrence and migrations of the istiophorid fishes in Taiwan waters according to genera, the fishes of the genus Makaira are abundant in the winter in the area of the Japan Current rather close to shore; the shortnosed spearfish we know little about because there have been no investigations at other seasons of the year, but it is also abundant in the winter in the Japan Current area. However, it is markedly pelagic and its occurrence is limited to the far off-shore waters. The sailfish is abundant around the island throughout the year but is particularly abundant in the summer, and its migrations extend very close to the coast.

Table 7.--Numbers of spearfishes handled at the Suō market (by months and by species; upper figure is for 1934, lower figure for 1935)

Month	White marlin	Striped marlin	Black marlin	Sailfish
1	1,446	604	156	65
	1,401	1,488	80	180
2	1,202	244	423	20
	902	913	258	181
3	1,361	225	223	24
	1,013	502	250	115
4	331	310	11	253
	462	97	169	97
5	107	12	29	334
	34	5	5	179
6	12	3	17	530
	6	6	3	256
7	4	4	7	308
	0	0	0	18
8	11	1	30	253
	0	0	0	0
9	8	5	9	58
	4	5	3	46
10	648	632	49	784
	205	420	145	229
11	1,990	814	86	236
	1,546	926	212	550
12	1,267	1,030	116	61
	2,787	2,458	149	267
	8,387	3,884	1,156	2,926
	8,360	6,820	1,274	2,118

The broadbill swordfish is taken only rarely around the whole island, the greatest number of landings being made at Takao; these landings, however, are not numerous enough to be recorded in the statistics. At Suō in most years they are very rare, but in November and December of 1936 they were rather abundant and several were landed every day.

B. Spawning Habits

It appears that except for the broadbill swordfish almost nothing has been recorded concerning the life history of the spearfishes. In Taiwan large numbers of spearfishes are landed and they migrate in rather dense schools into the waters east of the island, but these migrations have almost no direct connection with spawning. However, among the sailfish and shortnosed

spearfish some specimens which are about to spawn or are engaged in spawning are discovered. The author has previously made some observations in the South Seas[15] on the ripe eggs of the sailfish. The juvenile sailfish have a strongly marked positive phototropism, and in the waters east and south of the island they are taken from time to time with night-lights. The fishery experiment stations of both Takao Province and Taihoku Province have specimens under 20 cm. in length which were taken in this manner, and in this laboratory several specimens of about 30 cm. are preserved that were taken in the same manner off Hong Kong. Among the sailfish that are taken in set nets along the coast of eastern Taiwan in the summer there are individuals with highly developed gonads. Of course, they are still quite a way from having ripe eggs, but it is thought that they are not too far off from spawning. Considering the appearances of juveniles and the degree of ripeness of these ovaries, it is possible to imagine that the sailfish spawn somewhere not very far from Taiwan.

Among the spearfishes which migrate into the waters east of Taiwan in the winter, the gonads are very immature and in many cases it is difficult to distinguish the males and females with the naked eye, but it is clear that spawning is being carried on by the shortnosed spearfish occurring farther off shore[16].

The research vessel Shōnan Maru of this laboratory on November 22, 1936, fished a station at 21°46'30"N., 124°22'30"E., and at 2:00 P.M. one shortnosed spearfish was brought aboard still alive. When lifted out of the water, the fish released eggs all over the deck. This fish was captured on a branch line 60 m. long, and since wooden floats had been placed above each of the branch lines, the depth at which the fish was hooked was not greater than 60 m. Since it is probable that because of the force of the current the branch lines hang at somewhat of an angle in the water, in actuality the depth at which the fish bit was probably 10 or 20 percent less than 60 m. The observations recorded in the field notebook were as follows:

The air temperature at the station at noon that day was 24.6°C., atmospheric pressure was 763 mm., the sky was clear, surface water temperature was 25.8°C., as was that at the 60 m. level. A thermometer inserted into the anus of the shortnosed spearfish showed a body temperature of 25.4°C. The snout of the fish was slightly broken, but the distance from the tip of the snout to the keels on the caudal peduncle was 1,524 mm. and the weight of the fish was 12.3 kg.

The eggs that were released were preserved in alcohol and brought back, but as they had already become white and opaque it was not possible to see their internal structure. The size of the eggs was about 1 mm. The ovarian eggs of this specimen were preserved by freezing together with the fish and when they were looked at later it was found that they were very poorly developed, the eggs were small, and the oil globules were clustered like grapes (plate 11). At the same time a number of other specimens captured were investigated and the majority of them had the gonads either ripe or nearly ripe so that it was possible to make observations of a large number of ripe eggs. The eggs in the ovaries that were thought to be nearly mature were almost colorless and translucent and the yellowish-brown oil globules had united until there were only two of them (plate 11). The eggs at this stage of development had a diameter of about 0.8 mm. According to the observer who witnessed the release of the eggs they were released in a whitish mucus and were almost colorless and clear.

The gonads of both males and females are of a peculiar form as was pointed out in section I (plate 11).

There is thus no doubt that spawning of the shortnosed spearfish takes place off the eastern side of the island, but we may consider further that the spawning of the spearfishes probably does not, as in other fishes, take place in great groups over a very short period of time, but probably continues over a long period and over a broad area of the sea. The reason for this belief,

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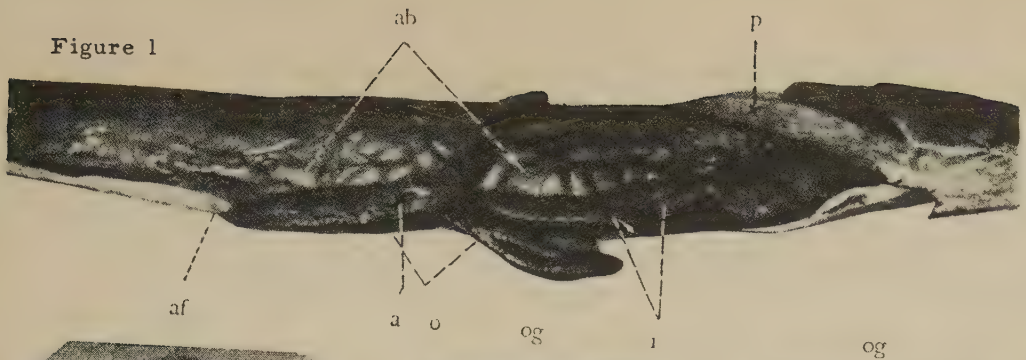
[15] Nakamura, Hiroshi. Zool. Mag. 44, 244, 1932

[16] Nakamura, Hiroshi. Zool. Mag. 49, 233-238, 1937

Figure 1



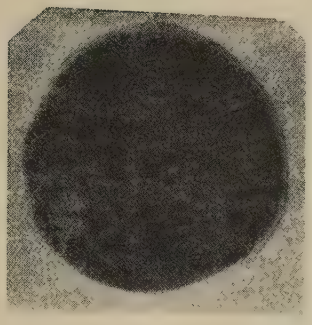


Figure 2

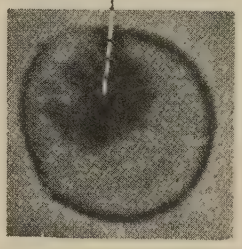


Figure 3

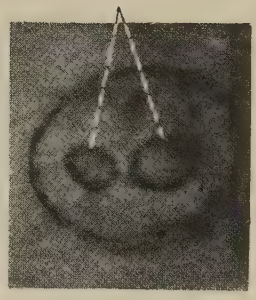


Figure 4

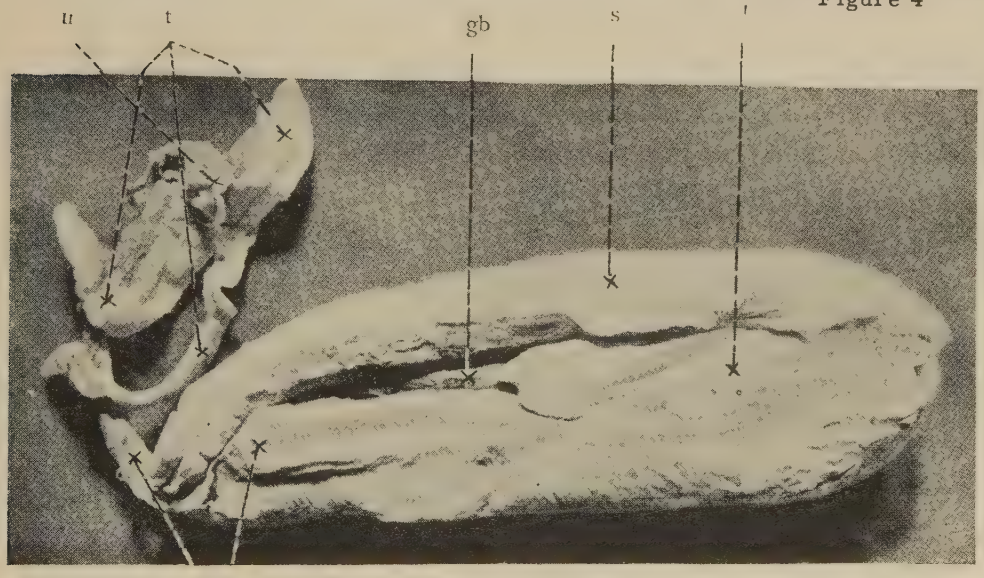


Figure 5

Plate 11.--Figure 1 - ovary (about 1/10 natural size). a - anus; ab - air bladder; af - first anal fin; i - intestine; o - ovary; p - pectoral fin. Figure 2 - ripe egg (spawned egg preserved in alcohol aboard ship X 35). Figure 3 - unripe egg (about times 40), og - oil globule. Figure 4 - mature egg (taken from ovary) X 36, og - oil globule. Figure 5 - testis (about 1/3 life size) gb - gall bladder; i - intestine; l - liver; s - stomach; t - testis; u - ureter

although it is not known how many days are necessary for the maturation of the eggs, is that it is known that in a single sea area over a period as long as 2 months fish with ripe eggs and those with unripe eggs are found mingled together.

As far as the life history of the shortnosed spearfish is concerned, it is thought that it will be comparatively easy to clarify the whole picture by means of large scale fishing experiments and marine biological investigations.

III. FISHERIES

It has already been stated that among the fishery products of Taiwan the spearfishes occupy the first place after the cultivated milkfish. The amounts of spearfish handled at the fish markets in the various governmental subdivisions in 1933 are as follows:

Table 8.--Amounts of spearfishes handled by governmental subdivisions

Area	Weight	Value
	kin	yen
Taihoku Province	3,916,745	770,171
Shinchiku "	27,686	4,938
Taichū "	347,009	69,797
Tainan "	296,909	57,687
Takao "	2,822,332	453,022
Taitō District	42,968	8,375
Karenkō "	140,395	30,148
Hōko "	-	-
Total	7,594,044	1,394,138

1 kin = 1.32 lbs.

Thus the spearfishes occupy a very important position among Taiwan's fisheries, but there appears to have been no particular fishery for these fishes before the Japanese occupation of the island. Even after the Japanese occupation the development of this fishery has lagged far behind that of the other fisheries.

The spearfish fisheries may be generally divided as follows:

a. Harpoon fishery
b. Longline fishery
c. Other fisheries

A. Harpoon Fishery

(a) History

Before the change of regimes this type of fishery did not exist at all. The beginning of the harpoon fishery in Taiwan dates back to 1923, when fishermen from Oita and Ehime prefectures came here to start this fishery. Since they had good results, the development proceeded rapidly until the fishery reached its present flourishing condition. At present there are actually more than 150 vessels engaged in this fishery. When the fishery was first being established, its operating area was limited to the vincinity of Suō, but as the number of vessels operating increased and the vessels themselves were built larger the fishing grounds were gradually extended both north and south until at present the operating radius is from off Taitō on the south to the vicinity of Hōkasho on the north. However, the fishing grounds shift their position with the season, being in the south at the beginning of the fishing season and moving north to the vicinity of Hōkasho

toward the end of the season, and consequently there is also a certain amount of change in the bases of the fishery with the season. In the past Suō and Keelung have been the bases, but with the completion of a fishing harbor at Shinkō in the Taitō district in 1932 this port came to be used as a base for the southern fishing grounds, and at present there are from 20 to 30 boats of this type using Shinkō as a base. However, Shinkō is geographically, as well as culturally, still inferior to Suō and Keelung as a base, and the amount of fish landed there is far inferior to that at the other two ports. In the near future, with the completion of the harbor works at Karenkō, this port too will naturally be used as a base, and there will be a complete array of bases from Shinkō on the south through Karenkō in the middle to Suō and Keelung in the north.

(b) Fishing boats

The fishing boats are of wooden construction with engines of 30-90 HP. At present the most commonly seen type is of 20-30 tons with 40-50 HP and a crew of from 4 or 5 to 10 men. This crew is made up of the captain, the engineer, and the fishermen. The fishing boats, depending on their size, have various kinds of large or small platforms built in the bow for the harpooner to stand on. The harpooner's platform is built somewhat like a box so as to protect him from danger and there is an iron rail (about 2 cm. in diameter) installed alongside him in case of danger. On the larger vessels there is room for two harpooners to stand, one on the right and one on the left, at the same time at the end of the harpooning platform. A lookout is kept on the bridge to search the surface of the sea for surfaced spearfishes. Recently simple platforms have been built atop the bridges for the convenience of the lookouts on an increasing number of vessels. In the summer these vessels turn to fishing for coral (see plate 12).

(c) Fishing gear and methods

The main part of the gear is the harpoon. On a pole of oak about 4.5 m. long, an iron with three prongs about 8 mm. in diameter is placed and the harpoon points are installed on each of these three tips. The harpoon points are of steel, about 11.5 cm. long, and each one is attached to a wire cable. These wire cables are joined together and go through a ring on the upper part of the handle where they join a harpoon line made of 360 strands of No. 20 line. The harpoon line has about 300 fathoms per basket, and depending on the necessity any number of these baskets can be joined together.

When the lookout sights a surfaced marlin, the boat gives chase at full speed and when it reaches an appropriate distance the harpooner throws the harpoon at the fish. If the harpoon point strikes the fish, it comes loose from the handle and remains within the body of the fish, and the handle is recovered by a separate line attached to it. The fish is played on the harpoon line by hand until it is finally hauled into the boat.

/Translator's note: sketch of a complete harpoon and one harpoon point appearing here in the original have been omitted from the translation./

(d) Kinds of fish captured

Among the kinds of spearfish taken by the harpoon fishery, the white marlin is most numerous followed by the striped marlin, the black marlin, the sailfish, and the broadbill in that order.

As has already been clearly shown in table 7, there is a change in the species composition of the catch throughout the season which can be conveniently shown in the following table.

Since tables 7 and 9 also include the catches from fisheries other than the harpoon fishery, the sailfish and black marlin predominate. It is clear, however, that during the season when the harpoon fishery is most active the black marlin is taken in greater numbers than the sailfish.

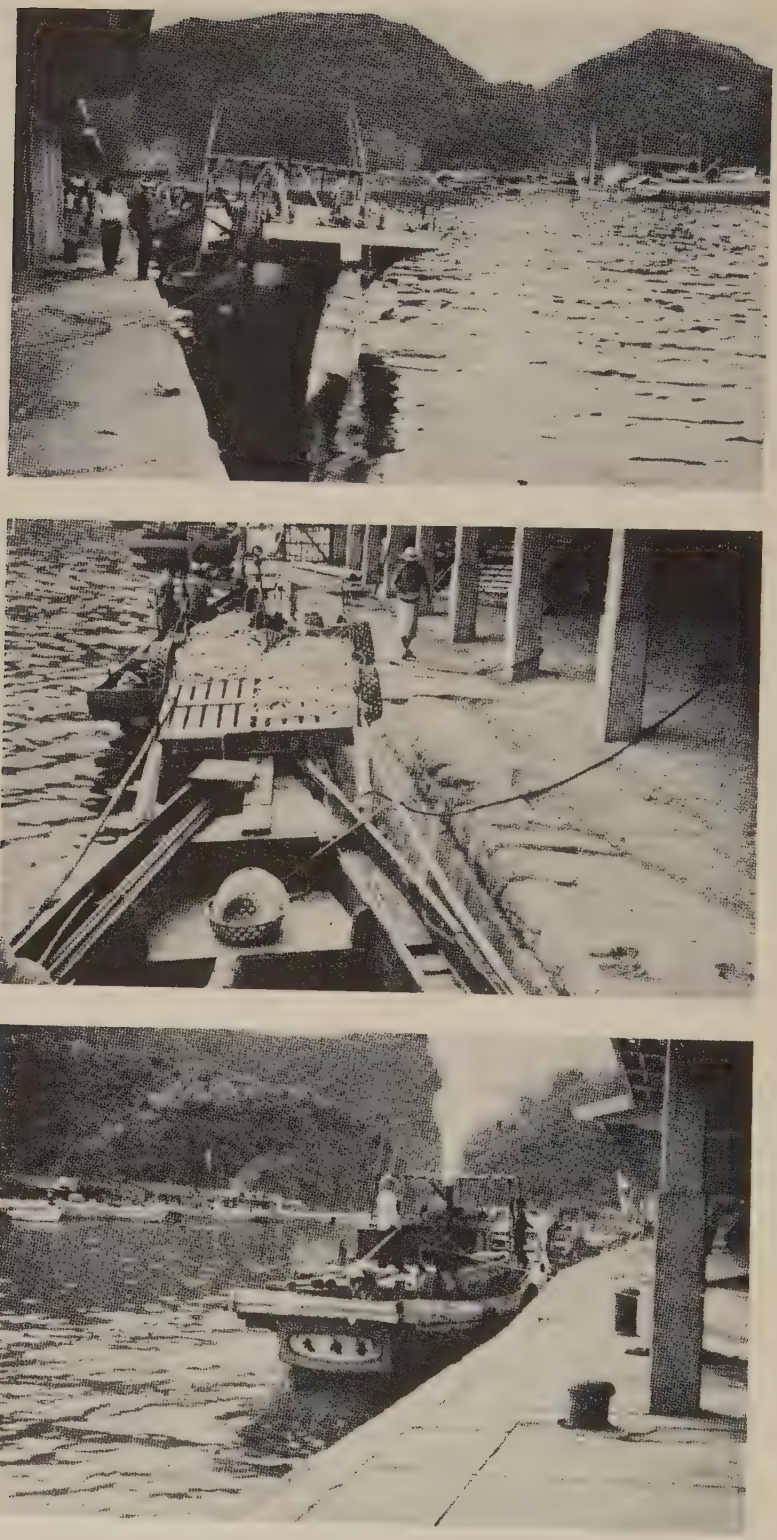


Plate 12.--Three pictures of fishing boats.

Table 9.--Numbers of fish handled by species and months (statistics from the Suō fish market for one year from July 1934 to June 1935)

Year and Month	White marlin	Striped marlin	Black marlin	Sailfish
1934				
July	4	4	9	308
August	11	1	30	253
Sept.	8	5	9	58
Oct.	648	632	49	786
Nov.	1,990	814	86	236
Dec.	1,267	1,030	116	61
1935				
Jan.	1,401	1,488	80	180
Feb.	902	913	258	181
March	1,013	502	250	115
April	462	97	169	97
May	34	5	5	179
June	6	6	3	256
Total	7,748	5,497	1,064	2,710

B. Longline Fishery

Before Taiwan was taken over by the Japanese there was no such fishery as this in the island. A start was made in 1913, when the Government-General began experimenting, and thereafter the development was swift. The fishery is carried on most actively in Taihoku and Takao provinces. In 1918 some of the catch was successfully exported to Japan and cultivated milkfish and mullet began to be used as bait. In 1923, with the completion of the fishing boat harbor at Suō, a longline fishery based at that harbor was begun. The number of boats based at Keelung, Suō, and Takao increased remarkably and then in 1932, with the completion of the fishing boat harbor at Shinkō, the fishery also got a foothold there and has continued to develop more and more. In the early period of this fishery sailing vessels were used, but now only powered vessels are employed. The operating radus was about 20-30 miles off shore at that time, but at present the fishing grounds in the north have expanded to more than 100 miles from the coast and the boats based at Takao actually have an operating radius of over 1,000 miles, fishing in the Sulu Sea and the Celebes Sea. Consequently larger and larger vessels have been built and there are already some in the 100-ton class.

The fishing season is approximately half the year, from September to April, and in the north there are more than 250 vessels participating in this fishery, the catch being principally spearfishes and sharks and having a value of 500,000 yen. Some of these fishing vessels engage in the coral fishery during the summer.

The total number of longline boats based at Takao is about 200, and their catch has a total value of 1,500,000 yen. Of course this is principally tunas, of which the yellowfin is most numerous, the value of the spearfishes being about 600,000 yen.

In the north, that is at Suō, the bait used is largely mackerel. When mackerel are not available, it appears that milkfish reared in the southern part of the island are used. When the mackerel are available, small powered vessels operate mackerel longlines and a part of their catch is immediately used on the following day as bait for longline fishing for sharks, spearfishes, and tunas. The fishing boats based at Takao formerly used as bait the ginkagami (native name "poepo") /Mene maculata/, but in recent years pond-cultured milkfish have come to be widely used, and it appears that squid are also sometimes used.

There is some difference in longline gear construction between the north, where spearfishes are the principal catch, and the south, where the fishery is primarily for tunas. In the north the gear principally designed to catch spearfishes has mainlines 480 fathoms in length with twelve 8-fathom branch lines at 40-fathom intervals (with 20 fathoms of mainline between the last branch line and the end of the basket on each end). The tip of each branch line is provided with a 2-fathom sekiyama, 1 fathom of wire, and on the wire is a round 3.8-inch hook. Every two branch lines there is a 7-fathom float line, a total of 4 per basket. At the top of each float line a 3-foot long paulownia log is attached as a float. The material for the line is 360-thread No. 20 cotton.

In the south, where the fishery is primarily for tunas, the mainline is 390 fathoms long with nine 12-fathom branch lines at 40-fathom intervals (with 25 fathoms at the ends so that there are 50 fathoms between the first branch lines of adjacent baskets, the float lines being attached in the middle).

The sekiyama is 4 fathoms long, the wire 2 fathoms, and the hook is similar to that described above. Every three branch lines an 8-fathom float line is attached, so that there are 3 per basket. For the floats at the ends of the baskets, glass balls 8 inches in diameter are used, the other floats being paulownia billets. The material for the mainline and branch lines is 160-thread No. 10 cotton, while the branch lines are 360-thread No. 20 cotton.

Each of these units is actually stored in a basket. Depending on the size of the vessel the amount of gear set varies, but the number carried by a single boat will be 50-100 baskets. These baskets are fastened together while being set and the floats are attached so that the line hangs down below the surface of the water.

The majority of the boats based at Suō and Keelung are engaged in day fishing, but the large boats sometimes make cruises of about a week's duration. The boats based at Takao make cruises of about 2 weeks ordinarily.

C. Other Fisheries

The harpoon fishery and the longline fishery make up the greater part of the spearfish fisheries, however, other Formosan fisheries which take spearfishes can be cited, such as the trap-net fishery and the trolling fishery. However, compared with the two mentioned earlier, their production is extremely small.

(a) Trap-net fishery

From April to the first part of July very dense schools of sōdagatsuwo /Auxis sp./ migrate into the coastal waters of eastern Taiwan. A large number of set-nets are placed everywhere along the coast to capture these fish. In these set-nets, besides the Auxis, other miscellaneous species are caught, including quite a few cybiids and spearfishes. According to the fishing statistics for 1934, the amount of spearfishes captured by set-nets for the whole island was 9,776 kin /12,914 lbs./ with a value of 1,639 yen. The catch for the Taitō and Karenkō districts was 9,426 kin /12,442 lbs./ valued at 1,551 yen and the majority of the fish were sailfish.

(b) Trolling fishery and others

Besides the set-net fishery, spearfishes are caught in other miscellaneous fisheries, according to the fishery statistics for 1934 to the amount of about 50,000 kin /66,000 lbs./ with a value of around 9,000 yen throughout the whole island. It must be stated that this is a very small amount in comparison with the value of the catches of 470,000 yen for the harpoon fishery, and 910,000 yen for the longline fishery.

D. Handling and Marketing of the Catch

In the longline and harpoon fisheries based at Keelung, Suō, and Shinkō the fishing grounds are very close to the bases, and therefore the majority of the boats leave port before dawn for

the fishing grounds, operate for one day, and return to port in the evening. On these boats nothing in particular is done to the catch aboard the vessel, the fish simply being carried on deck back to the base. However, on the larger harpoon boats the cruises are for about 1 week, and on the longline boats based at Takao, where the base and the operating area are widely separated in distance, a rather large number of days is required per cruise. On such fishing boats the captured spearfish have their snouts and tail fins cut off and they are wrapped in sulphite paper or cloth and stowed in ice before being brought back to the market.

When the fish are landed at the market they are bought by middle men at auction. The buyers immediately cut off the heads, gut the fish, cut off the fins, and place the fish in boxes for transport to the various areas of consumption. The consumption of spearfish in Taiwan is about 20 to 30 per cent of the total catch, the rest being exported to Japan or to Manchuria and Korea. The prices, of course, fluctuate with the season and economic conditions, but throughout 1935 the average price at Keelung was 42 yen per 100 kin. At the end of the year and beginning of the year the prices are highest, there being ordinarily a gradual decline in price away from this period. Depending on the season there are fluctuations of some extent, but the striped marlin is the highest priced, followed by the white marlin, the black marlin, and the sailfish in that order. The broadbill is very cheap. Hardly any shortnosed spearfish are brought in and they have no particular name, but those handled at the Suō fishing market are said to be all treated the same as the sailfish.

APPENDIX

(1) Table of scientific names and Japanese names:

Scientific names	Japanese names
Istiophorus orientalis	bashōkajiki (baren)
Makaira marlina	shirokajiki (shirokawakajiki)
M. mazara	kurokajiki (kurokawakajiki)
M. mitsukurii	makajiki (akakajiki)
Tetrapturus angustirostris	fūraikajiki
Xiphias gladius	mekajiki (tsun)

(2) Table of Japanese and Formosan names:

Japanese names	Formosan names*
akakajiki (makajiki)	紅肉旗魚
kurokajiki (mazara)	烏皮旗魚
shirokajiki	立翅旗魚
tsun (mekajiki)	丁版舊旗魚
baren (bashōkajiki)	雨傘旗魚
fūraikajiki	none
makajiki (akakajiki)	紅肉旗魚
mazara (kurokajiki)	烏皮旗魚
mekajiki (tsun)	丁版舊旗魚

* Translator's note: As the translator is unable to supply the pronunciation of these names current in Formosa and translations of them are not particularly meaningful, they have been given here in their original form.

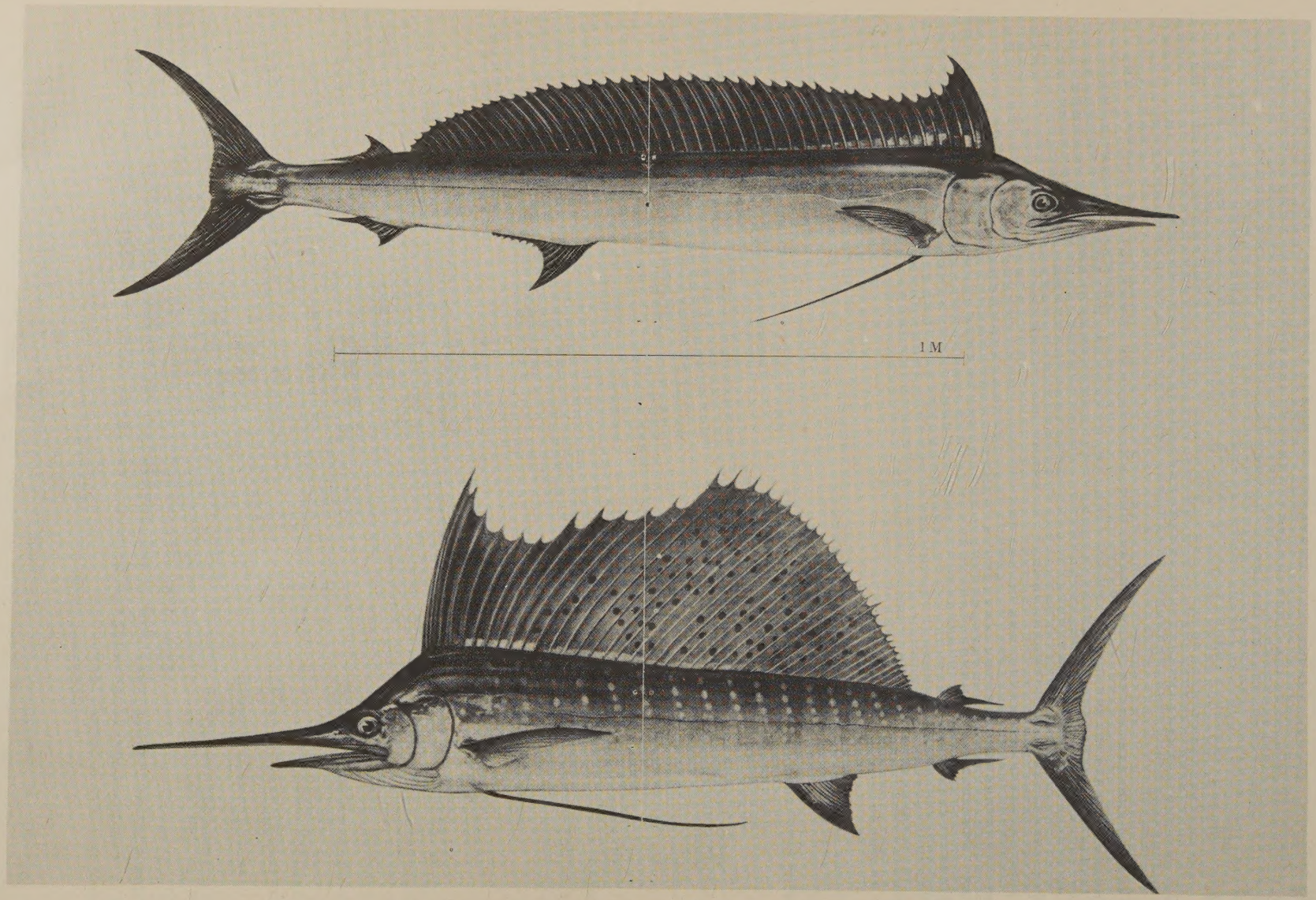


Plate 13.--Figure 1 (upper) shortnosed spearfish; Figure 2 (lower) sailfish.

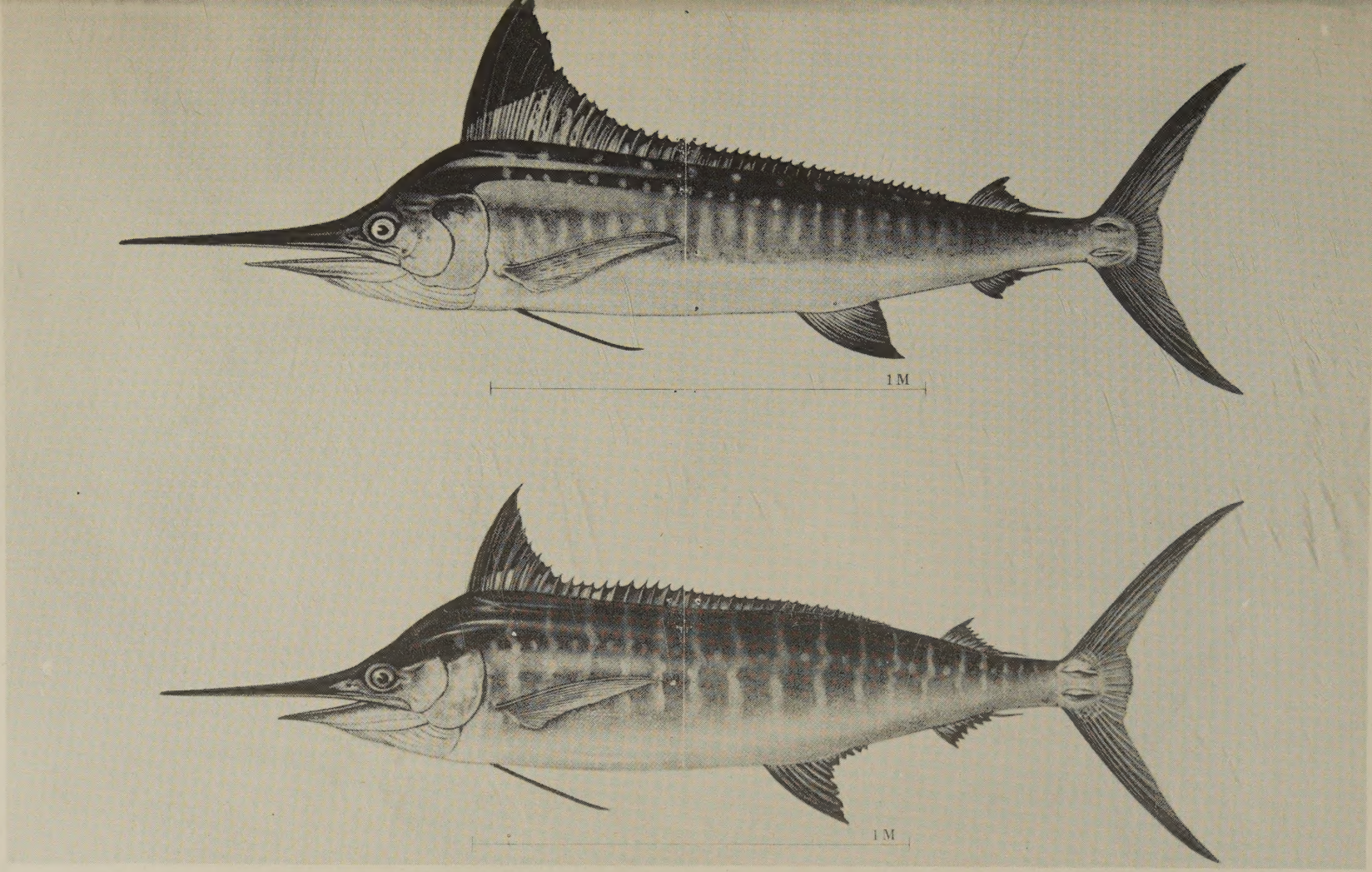


Plate 14.--Figure 1 (upper) striped marlin; Figure 2 (lower) black marlin.

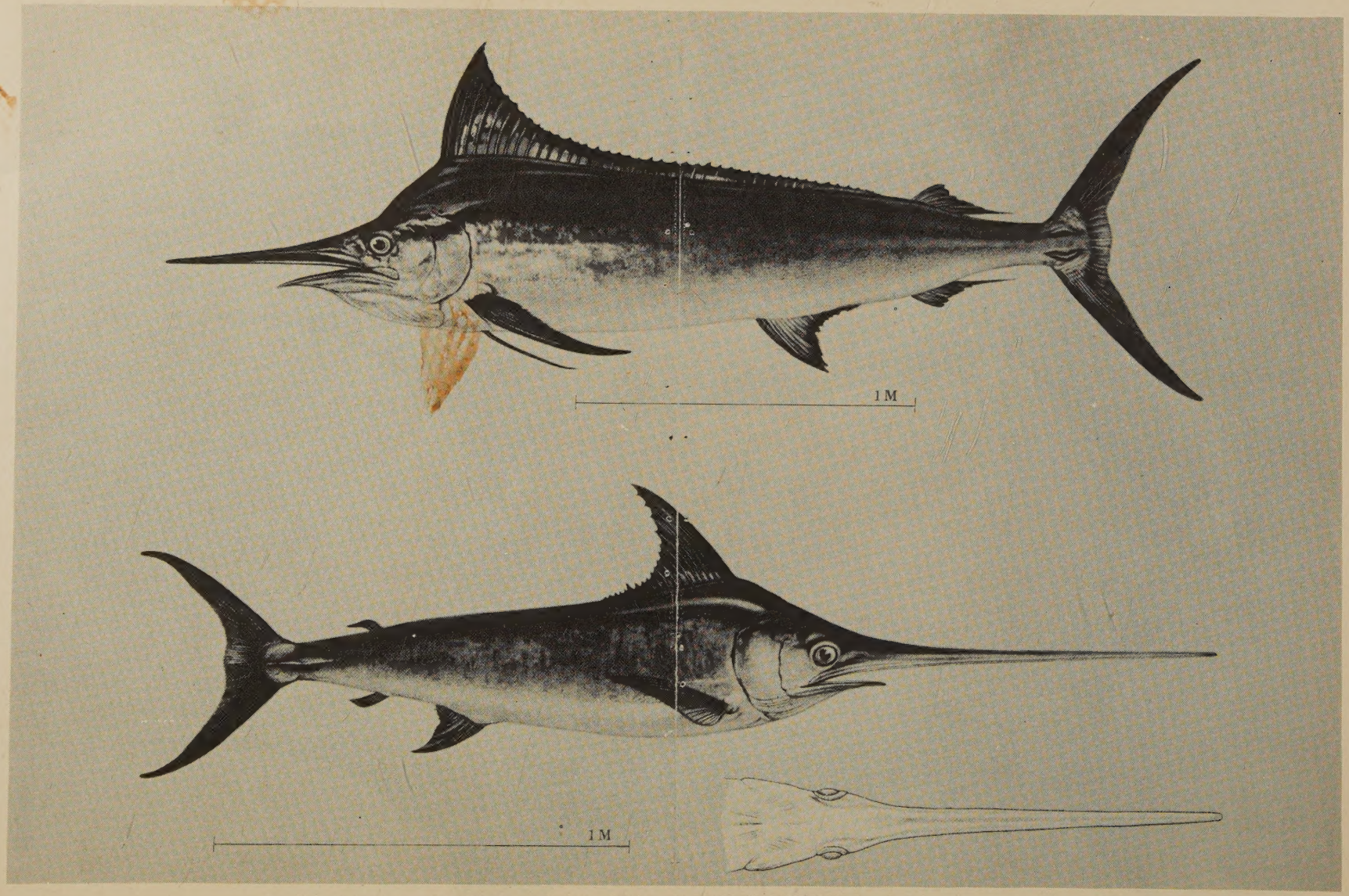


Plate 15.--Figure 1 (upper) white marlin; Figure 2 (lower) broadbill.